Exploring policy protection in biofuel niche development : a policy and strategic niche management analysis of Dutch and Swedish biofuel development, 1970-2010

DOI:
10.6100/IR762655

Document status and date:
Published: 01/01/2013

Document Version:
Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

Exploring policy protection in biofuel niche development

Johanna Ulmanen

This research has been made possible by:
Organisation for Scientific Research (NWO) and Eindhoven University of Technology, School of Innovation Sciences.

ISBN 978-90-8891-744-8

Cover design: Maria Ärlemo

Cover Lay Out by: Uitgeverij BOXPress, 's-Hertogenbosch

Printed and Published by: Uitgeverij BOXPress, 's-Hertogenbosch

Exploring policy protection in biofuel niche development

A policy and Strategic Niche Management analysis of Dutch and Swedish biofuel development, 1970-2010

PROEFSCHRIFT

ter verkrijging van de graad van doctor aan de Technische Universiteit Eindhoven, op gezag van de rector magnificus prof.dr.ir. C.J. van Duijn,
voor een commissie aangewezen door het College voor Promoties, in het openbaar te verdedigen op donderdag 28 november 2013 om 14:00 uur

door

Johanna Heleena Ulmanen

geboren te Huddinge, Zweden

Dit proefschrift is goedgekeurd door de promotoren en de samenstelling van de promotiecommissie is als volgt:

voorzitter:	prof.dr A.G.L. Romme
1e promotor:	prof.dr.ir. G.P.J. Verbong
2e promotor:	prof.dr. J.W. Schot
copromotor(en):	dr.ir. R.P.J.M. Raven
leden:	prof. S. Jacobsson PhD (Chalmers University of Technology) prof.dr. J. Grin (UvA) dr. H.A. Romijn

Acknowledgements

A central concept of this thesis is protection, that is, various nurturing and shielding measures that have the potential to stimulate sustainable development. It shows that two quite different biofuel development trajectories have shared experience that protection is a prerequisite for development, albeit in a non-linear manner. The relation between protection and development found in this work also fits the development trajectory of my PhD project: a bumpy road made smoother by the great number of people who have given me support, inspiration and joy – people to whom I owe a debt of gratitude.

I am very grateful for the learning process which I have undergone by writing this thesis – a process which would not have thrived without the outstanding supervision and encouragement of my supervisors, Geert Verbong and Rob Raven. They challenged and inspired me intellectually, and guided me back on track when I lost direction. The meetings with my professor, Johan Schot, also provided invaluable intellectual inspiration and structure to my work. His role as professor was in the final few months taken on by Geert Verbong. I also want to recognize the input of Frank Geels, who was my supervisor in the initial months of my work. He and many others have inspired me with interesting literature and thoughts in our common reading clubs. Nor must I forget all the administrative matters that my secretary, Mieke Rossou, facilitated throughout my thesis work.

My research endeavour has brought me into contact with various inspirational and knowledgeable people in the Netherlands and Sweden. My involvement with the Knowledge Network for System Innovation and transitions (KSI) has been of particular value. Colleagues such as John Grin and Anne Loeber at the University of Amsterdam have given me most useful theoretical feedback and Roald Suurs and Marko Hekkert at Utrecht University have been very helpful with sharing empirical data. I am also very grateful to Staffan Jacobsson, who arranged a visit for me to the Division of Environmental Systems Analysis at Chalmers University in Gothenburg. He and a handful of colleagues, such as Karl Jonasson, Björn Sandén and Hans Hellsmark, provided key inputs for my research. I also thank the Biomass Group at the Technical University of Eindhoven, for allowing me to attended regular meetings on biofuel and bioenergy development. Kees Daey Owens in particular dedicated much of his time to guide me through the jungle of biofuel technology. I also owe much to my informants, treated anonymously in this work, who shared their experience and knowledge of the biofuel development trajectory in Sweden and the Netherlands.

I also want to acknowledge my colleagues at Maastricht University, who inspired me to choose an academic career in the first place – especially my mentor, Louk Box, who encouraged me to embark on a PhD, and colleagues such as Jessica Mesman, Marjolein van Asselt and Wiebe Bijker. This eventually led to Eindhoven University of Technology, where I carried out my research.

On a both an intellectual and a social level, my colleagues at Eindhoven University have provided essential support during my PhD years. The colleagues I spent the most time with were the PhD students, Niels Schoorlemmer, Bram Verhees and Marlous Dignum, who joined me in the KSI research school. That is not to neglect colleagues such as Ruth Mourik, Saurabh Aurora and Deborah Tappi, and and other history of technology PhD students and colleagues, such as Frank Schipper, Vincent Lagendijk, Suzanne Lommers, Irene Anastasiadou, Alec Badendoch, Judith Schueler and Donna Mehos. I also want to thank all other colleagues at the TIS group in Eindhoven for making everyday life at the faculty so enjoyable.

The friends and colleagues I have got to know at the Stockholm Environment Institute have also been great fun and support during the last years of my thesis work. Special thanks go to Maria, Mats, Björn, Elise, Aaron, Maja, Rasmus and Peter.

I am also eternally grateful for my close friends and family. I would never have been able to do this without your love and support. Many special persons meant a lot to me in different periods in life, you know who you are and I thank you all. My childhood friends – Maria, Cilla and Lina – deserve a special recognition for always backing me up in good and hard times.

Last but not least, I thank my family – my parents, my brother and sisters – for all their care and love. Dearest sister Petra, thanks for being there for me. My warm thanks also go to the Golsteyn family for their care during my years in the Netherlands.

Stockholm, 16 October 2013

Acronyms and abbreviations

AEB	Afval Energie Bedrijf (the municipal waste combustion company of Amsterdam)
AFV	Alternative Fuel Vehicles
ATO	Agrotechnology and Food Innovations
BAFF	Bio Alcohol Fuel Foundation
BER	Bio-ethanol Rotterdam BV
BEST	Bio Ethanol for Sustainable Transport
BFR	BioFuel Region
BIGCC	Biomass Integrated Gasification Combined Cycle
BIG-FIT	Biomass Integrated Gasification FIscher-Tropsch
BLG	Black Liquor Gasification programme
BRG	Business Region Göteborg
BSE	Bovine Spongiform Encephalopathy
BTG	Biomass Technology Group
BTL	Biomass to liquid
CAP	Common Agricultural Policy (EU)
CASH	Canada, America, Sweden Hydrolysis
CHAP	Concentrated Hydrochloric Acid Process
CHRISGAS	Clean Hydrogen-Rich Synthetic Gas
CIG	Coal Injection Gasification project
CLM	Centre for Agriculture and the Environment
CNG	Compressed Natural Gas
CO_2	Carbon dioxide
CO	Carbon oxides
CHP	Combined heat and power
CPC	Chemical Processing Consult
DFE	Delegationen för energiforskning (Delegation for Energy Research) (Sweden)
DME	Dimethyl Ether
DOE	Department of Energy (US)
ECN	Energie Centrum Nederland (Energy Research Centre of the Netherlands)
ECN	Energicentrum Norrland (Energy Centre Norrland) (Sweden)
EEB	European Environment Bureau
EET	Economics, Ecology and Technology programme
EOS	Energie Onderzoek Subsidie (Energy Research Subsidy)
EOS KTO	EOS, KOrte Termijn (EOS,short-term research)
EOS NEO	EOS, Nieuw Energy Onderzoek (EOS, new energy research)
EOS LT	EOS, Lange Termijn (EOS, long-term research)
EOS UKR	EOS, Unieke Kansen Regeling (EOS, unique chances arrangement)
EPA	Environmental Protection Agency (Sweden)
ETBE	Ethyl Tert-Butyl Ether
ETC	Energitekniskt Centrum (energy technical centre)
EU	European Union (EU)
EWAB	Energy extraction from Waste and Biomass
EZ	Ministry of Economic Affairs (the Netherlands)
FAME	FAtty Methyl Esters
FFVs	Flexi Fuel Vehicles
FT diesel	Fischer Tropsch diesel
GAVE	Climate neutral gaseous and liquid energy carriers

GDA	Gemeentelijke Dienst Afvalverwerking (Amsterdam Municipal Waste Processing Agency)
GDP	Gross Domestic Product
GMOs	Genetically Modified Organisms
GTL	Gas to liquid
HPA	Hoofdproductschap Akkerbouw (organization of agricultural commodity boards)
HTU	Hydro Thermal Upgrading
HTW	High Temperature Winkler
ICGCC	Integrated coal gasification combined cycle
IMF	International Monetary Fund
IMSA	Amsterdam Institute for Environment and Systems Analysis
IPCC	Intergovernmental Panel on Climate Change
JTI	Institutet för jordbruks- och miljöteknik (Swedish Institute of Agricultural and Environmental Engineering)
IVL	Svenska Miljöinstitutet (Swedish Environmental Research Institute)
KEPRO	Ketenproject raapzaadolie (Project for rapeseed oil)
KFB	Kommunikationsforskningsberedningen (Communications Research Board)
KLIMP	Climate Investment Programme
KNV	Royal Dutch Transportation
KTH	Royal Institute of Technology, Stockholm
LIP	Local Investment Programme
LPG	Liquefied Petroleum Gas
LRF	Lantbrukarnas Riksförbund (Federation of Swedish Farmers)
LVN	Ministerie van Landbouw, Natuur en Voedselkwaliteit (Ministry of Agriculture, Nature and Food Quality)
MTBE	Methyl Tert-Butyl Ether
MLP	Multi-Level-Perspective
MVO	Productschap Margarine, Vetten en Oliën (Product Board for Margarine, Fats and Oils)
NMP4	Nationaal Milieubeleidsplan (Fourth National Environment Plan) (Netherlands)
NO_x	Nitrogen oxide
NOM	Investerings en ontwikkelings maatschappij voor Noord Nederland (Northern Netherlands Development Association)
NRS	Nordvästra Skånes Renhållningsverk (North-western Skåne sewage plant)
Nutek	National Board for Industrial and Technical Development
OBL	Bio-ethanol uit landbouwgrond-stoffen(Development of Bio-ethanol from Agricultural raw materials)
OECD	
OPEK	Organisatie voor Plantenolie en Ecologische Krachtbronnen, Nederland(Organization for plant oils and ecological energy sources)
PBE	Foundation Platform Bio-Energy
PVO	Pure vegetable oil
REB	Regulerende energiebelasting(Regulative energy tax)
RED	Renewable Energy Directive
RET	Rotterdamse Elektrische TramRotterdam public transport company)
RIVM	National Institute of Public Health and the Environment (Rijksinstituut voor Volksgezondheid en Milieu)
RME	Rapeseed Methyl Esters
SDAB	State Propellant Technology Company (Statens Drivmedelsteknik AB)

SDE	Samenwerkings-verband Duurzame Energie (Agency for Research into Sustainable Energy)
SEKAB	Swedish Ethanol Chemistry
SER	Sociaal-Economische Raad (Socioeconomic Advisory Council)
SKAFAB,	Stockholms Kommuns Avfallsförädling (Stockholm municipal recycling)
SGC	Svenskt Gastekniskt Centrum (Swedish Gas Technical Centre)
SL	Storstockholms Lokaltrafik (greater Stockholm public transport)
SLR	Svenska Lantmännens Riksförbund (**The Federation of Swedish Farmers)**
SLU	Swedish University of Agricultural Sciences
SMAB	Swedish Methanol Development Company (Svensk Metanolutvecklings AB)
SMHI	Swedish Meteorological and Hydrological Institute (Sveriges meteorologiska och hydrologiska institute)
SNG	Synthetic Natural Gas OR Substitute Natural Gas
SNM	Strategic Niche Management
SOAB	Svenska oljebolaget (Swedish oilcompany)
SPI	Svenska Petrolium Institutet (Swedish Petrolium Institute)
SSEU	Stiftelsen Svensk Etanolutveckling (Foundation for Swedish Ethanol Development)
SSF	Simultaneous Saccharification and Fermentation
SSNC	Naturskyddsföreningen (Swedish Society for Nature Conservation)
STEV	Swedish Energy Agency
STFI	*Skogsindustrins tekniska forskningsinstitut* (Technical Research Institute of the Foresting Industry)
STS	Science, Technology and Society
STU	Styrelsen för teknisk utveckling (Swedish National Board for Technical Development)
TAB	Tankstations Alternatieve Brandstoffen (subsidy programme for alternative fuel pumps)
TFB	Transportforskningsberedningen (Swedish Transport Research Board)
THE	Tekniska högskolornas energiarbetsgrupp (the energy working group of the technical universities)
TIS	Technology Innovation Systems
TM	Transition Management
TNO	Nederlandse Organisatie voor toegepast-natuurwetenschappelijk onderzoek (Dutch organization for applied research)
TNO MEP	TNO Environment, Energy and Process Innovation
TRUST	Transportutveckling i storstad (big city transportation development)
VAT	Value Added Tax
VNBI	Vereniging Nederlandse Biodiesel Industrie (Netherlands Biodiesel Industry Association)
VNPI	Vereniging Nederlandse Petroleum Industrie (Dutch society of the petrochemical industry)
VROM	Ministry of Housing, Spatial Planning and the Environment (the Netherlands)
VVBGC	Växjö Värnamo Biomass Gasification Centre
WLTO	Western Land and Horticulture Organization
ÖCB	Överstyrelsen för civil beredskap (Swedish Emergency Management Agency)
ÖEF	Överstyrelsen för ekonomiskt försvar (National Board of Economic Defence)

Contents

Tables

Figures

1. INTRODUCTION

The current fossil fuel-based energy system is unsustainable.[1] Within the energy system the transport sector is particularly problematic. One of its most urgent problems is its effects on climate change. The transport sector accounts for 26% of global energy use and 23% of energy-related carbon dioxide (CO_2) emissions. Since the early 1970s, energy use in the transport sector has increased by 2-2.5% annually (IEA, 2010). If no action is taken, transport-related energy use and CO_2 emissions are likely to increase by 50% by 2030 and more than 80% by 2050. In order to reach the Intergovernmental Panel on Climate Change (IPCC) goal of a 50% cut in CO_2 emissions by 2050, the use of fossil fuels in the transport sector needs to be reduced drastically (IEA, 2009).

Among the many ways to deal with the CO_2 problem in the transport sector, alternative fuels such as biofuels[2] are a promising option. According to the ETP 2010 BLUE Map Scenario,[3] biofuels could substitute for 27% of fossil fuel in the transport sector and contribute to a 23% emission reduction by 2050, provided that sustainable biofuels are used which have high emission reduction and do not harm food security, biodiversity or society. There are already forces working in this direction, and 2% of the EU transport sector ran on biofuel in 2011 (IEA, 2011). This has been stimulated by EU policy, such as the Biofuel Directive (EC, 2003a) and its successor the Renewable Energy Directive (EC, 2009).

There are many types of biofuels and use differs significantly across countries (see box 1). Sweden has been a frontrunner, while the Netherlands along with the majority of European Union (EU) member states are lagging behind (see Figure 1).[4] Sweden and the Netherlands also differ in their biofuel development and adoption patterns. Initial plans in the 1970s for Swedish market expansion through low blends in fossil fuel were soon replaced by a focus on high-blend and pure-fuel niche markets, which led to market expansion in the 1990s. By contrast, initial Dutch biofuel experiments in the 1990s were geared towards the development of pure fuel niche markets. However, biofuel use remained peripheral until market expansion was achieved by using low blends in fossil fuels in the mid-2000s. Sweden has had a preference for the development of alcohols, both conventional and advanced, while the Netherlands has generally preferred advanced vegetable oil-based biofuels (Hillman, Suurs, Hekkert, & Sandén, 2008; Ulmanen, Verbong, & Raven, 2009). Based on these differences, I posed my research question:

How can we explain differences in biofuel niche development in Sweden and the Netherlands in the period 1970-2010?

---

[1] According to the UN Brundtland Commission (1987), sustainable development of the global environment and resources is defined as: 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (Brundtland, 1987).

[2] The term 'biofuel' refers mainly to liquid and gaseous transport fuels processed from biomass (see Box 1 for an overview), but also to other energy solutions based on biomass. To avoid confusion, this work uses the term biofuel to mean bio-based transport fuels alone, while bioenergy is used to refer to bio-based energy solutions.

[3] The IEA BLUE Map scenario is target oriented. It follows the IPPC target of halving global energy-related CO_2 emissions by 2050 (compared to 2005 levels) and examines the least-cost means of achieving that goal.

[4] Eurostat data from 2003-2010 show clear evidence of the difference between forerunners in biofuel use such as Sweden and Germany compared to the rest of the EU member states.

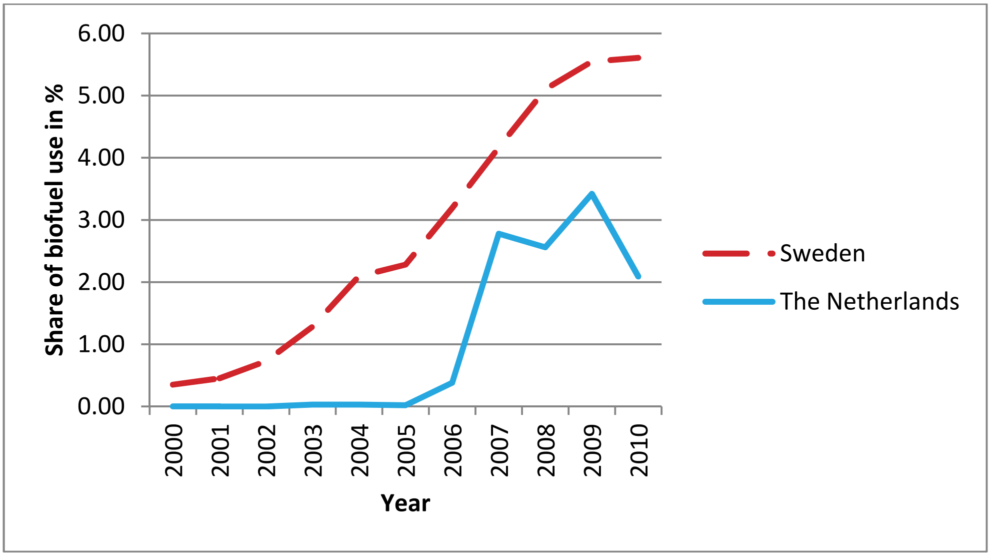

Figure 1: Share of biofuel use in the Swedish and Dutch road transport sector, 2000-2010

Source: Statistics Sweden, Energimyndigheten, Energigas Sverige (Sweden), Statistics Netherlands (the Netherlands)[5]

The differences in biofuel development can partly be explained by differences in natural resource base and industry structure. Early biofuel development in Sweden is likely to have been related to the lack of fossil fuels and the availability of large biomass resources for alcohol production. These biomass resources, such as forest material and bulk wheat, are in turn related to agriculture- and forest-related industries of which the latter are of key importance to the Swedish economy (Sandén & Jonasson, 2005; Ulmanen et al., 2009).[6] The Netherlands, on the other hand, is a small and densely populated country with limited access to biomass but close ties to the petrochemical industry through Royal Dutch Shell, the existence of a major European port for petrochemicals in Rotterdam and its large natural gas resources (Ulmanen et al., 2009).[7] This information is relevant, but is very crude and does not explain the timing, or the nature of development and adaptation patterns.

---

[5] The Swedish statistics include the use of bio ethanol, biodiesel and biogas, while the Dutch statistics include the use of biodiesel, pure vegetable oil, bio ethanol and ETBE, which is a fuel additive that contains bio-based ethanol and most probably other fossil chemical components. Share of biofuel use is calculated based on total energy use in the transport sector.

[6] The central role of the Swedish forest industry is demonstrated in 2010 data showing that it accounted for 10-12 per cent of total employment, turnover and added value in Swedish industry, and 11 per cent of Sweden's exports - equal to SEK 129 billion. In addition, the forest sector accounted for about three per cent of Sweden's gross domestic product (GDP). The industry is highly export-oriented: 85% per cent of the pulp and paper produced and 70 per cent of the sawn timber was exported in 2010. Sweden was the second-largest exporter of paper, pulp and sawn timber (Swedish Forest Industries Federation, 2011).

[7] The central role of the petrochemical industry and refinement as well as the natural gas reserves of the Netherlands is shown among others by Weterings et al. (2013), who argue that 20% of the Dutch government's income comes from the fossil fuel sector. Moreover, key Dutch industrial sectors (the chemical industry, transport of goods, horticulture and food industry) depend on this fossil fuel energy system.

To provide a more elaborate explanation of the differences between Sweden and the Netherlands, Strategic Niche Management (SNM) might be a promising theory. It has been successfully used in previous analyses of potentially sustainable technology development, of which some have focused on alternative propulsion in the transport sector such as biofuels (Van der Laak, Raven, & Verbong, 2007; Ulmanen et al., 2009) and electricity (Hoogma, 2000; Hoogma, Kemp, Schot, & Truffer, 2002).

The niche concept is central to SNM theory. *Technology niches* are 'protected spaces that allow nurturing and experimentation with the co-evolution of technology, user practices, and regulatory structures' (Schot & Geels, 2008). Hence, seen from this theoretical perspective, biofuels are sets of technology niches that can advance to the state of *market niches* with stabilized technology design and user demand. SNM has a set of hypotheses for why some niches are successful while others fail. These hypotheses are related to processes of network development, learning and the development of expectations. I analyse these below in order to gain insight in the differences between the Dutch and Swedish biofuel cases.

However, existing research has also highlighted that SNM contains one important weakness. Niches flourish because of protection (Schot & Geels, 2008), but the way in which protection comes about has not been fully investigated.[8] Protection is generated through policy processes or through specific market circumstances which favour its application (Schot & Geels, 2008). In the case of biofuels, protection has played an important role. Policy instruments at the local, national and EU levels have been crucial for biofuel development, of which the above-mentioned EU Biofuel Directive is a good example at the EU level. In addition, market circumstances have assisted biofuel development, such as the change in oil prices in the 1970s that triggered the initial interest and development of biofuels in Sweden mentioned above.

In this thesis I want to focus on the dynamics of government intervention. It has been claimed that irregular support in the Netherlands is one of the causes of less favourable development (see Hillman et al., 2008). Various theories can be used to research policy dynamics, as is discussed below. I use discourse analysis in this work. Hence, my thesis will use two complementary frameworks – SNM and discourse analysis – in one conceptual framework.

[8] Smith and Raven (2012) are exceptions who have explored this at a theoretical level.

Box 1: Types of biofuels

Biofuels were being produced and used at the end of the 19th century. For instance, Rudolph Diesel ran his first diesel engine on peanut oil, and the use of maize ethanol for propulsion was relatively common at that time. Until the 1940s biofuels were seen as viable transport fuels. However, this changed with decreasing fossil fuel prices. The oil crisis of the 1970s made biofuel viable once again. However, seen from a global perspective, it is only in the past 10 years that biofuel production has accelerated (see Figure 2) (IEA, 2011: 10).

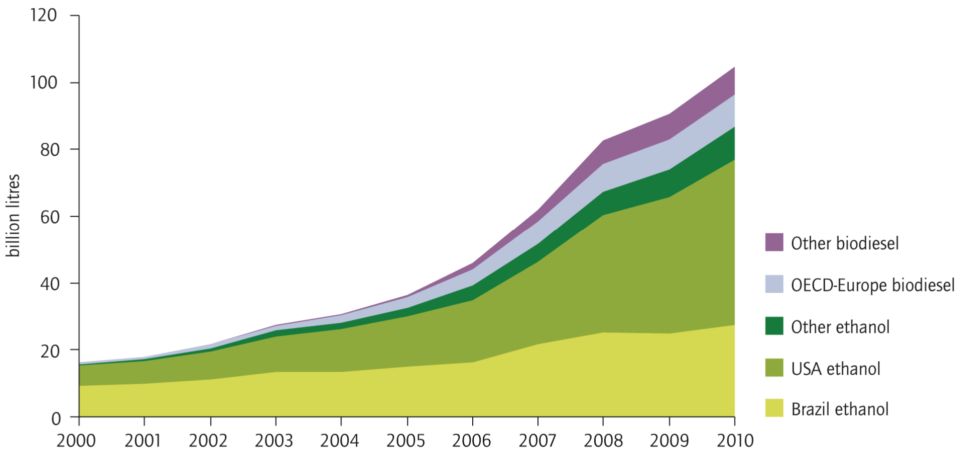

Figure 2: Global biofuel production, 2000-2010
Source: IEA (2011: 10)

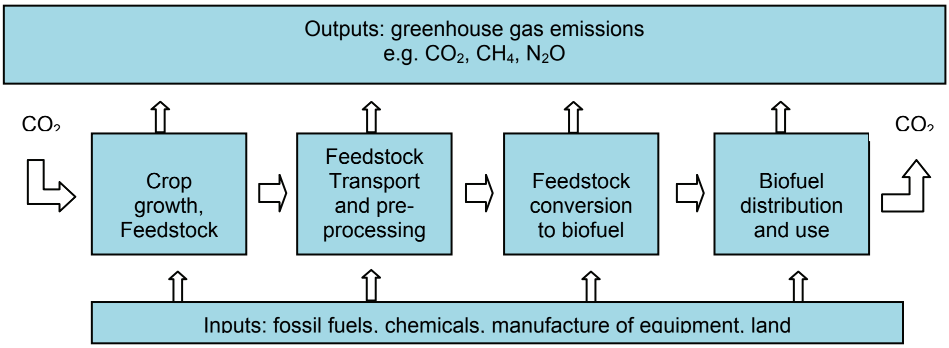

Figure 3: Greenhouse gas emissions from biofuel production and use
Source: Royal Society, London (2008: 5)

Biofuel is still not as cheap as fossil fuels. The motives driving biofuel development and implementation were related to concerns about energy security, the survival of the agricultural sector and reviving the rural economy. More recently, reducing CO_2 emissions in the transport sector has become the dominant driver (IEA, 2011). This builds on the idea of biofuels as more or less CO_2 emission neutral, i.e. the CO_2 emissions from biofuel use are consumed by the biomass grown for biofuel production. According to the Royal Society (2008), the amount of CO_2 emission reduction varies greatly between biofuels. The use of Brazilian sugar cane ethanol results in an 80% reduction in comparison to fossil fuels, while maize ethanol results in only a 10% reduction. As Figure 3 indicates, the amount of CO_2 emission reduction depends on a variety of factors throughout the production chain, such as the feedstock used (including crop yield), the method of transporting the feedstock, the efficiency of the conversion processes, fuel distribution and end use.

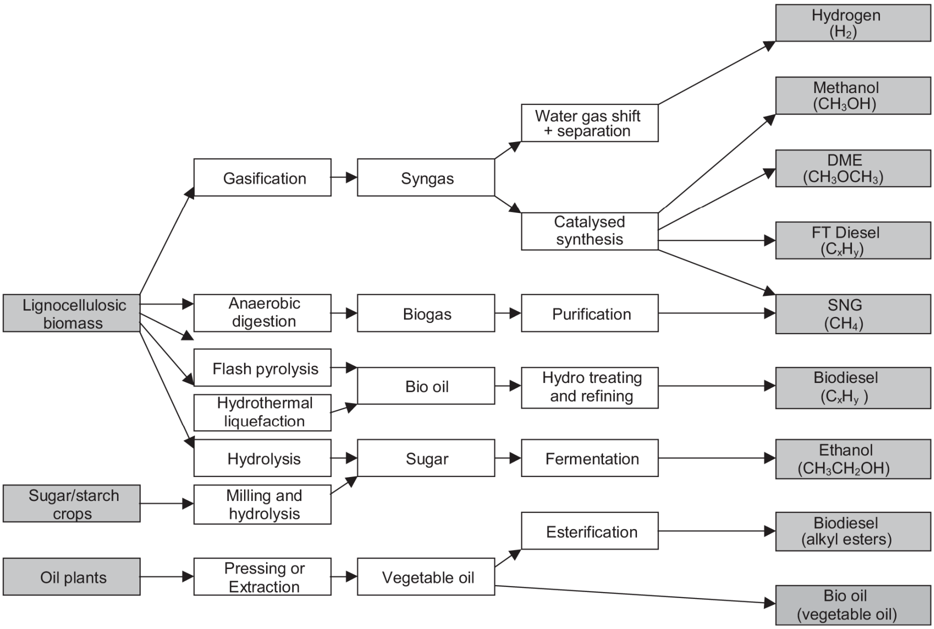

Figure 4: Overview of conversion routes from biomass to biofuels
Source: Hamelinck and Faaij (2006: 2)

Biofuels can be produced from a great variety of feedstocks and processing technologies (see Figure 4). Mature and conventional biofuels, such as bio oil, biodiesel, ethanol from crops and biogas from various food residues, rely on fairly simple processes. The ethanol production process is similar to that for producing alcohol for human consumption. It is a fermentation process, which uses sugar (e.g. sugar cane in Brazil) or starch crops (e.g. corn in the US or wheat in Europe) as feedstock. Bio oil is a pressed oil crop (e.g. rapeseed), similar to vegetable oil used for cooking. This vegetable oil can be refined to biodiesel by an esterification process. Biogas involves an anaerobic process and may be extracted from landfills or from municipal waste or other biomass in digesters. After cleaning and converting this gas to Substitute Natural Gas (SNG), it can be used for propulsion. Biogas digestion processes are sometimes separate from the conventional biofuel production process when using cellulose feedstock, which requires more advanced and less mature process technologies. For this reason, biogas comes under the definition 'Lignocellulosic biomass' in Figure 4, although the waste material used may not always be lignocellulosic. To avoid the use of expensive agricultural land and competition with food crops, several conventional biofuel producers are seeking alternative feedstock outside the agrarian sector. One promising route for both biogas and bio oil/biodiesel is the use of algae (Royal Society, 2008).

While some conventional processes are experimenting with feedstock other than food crops, lignocellulosic biomass usually requires more advanced biofuel production processes, as is indicated in the scheme above. There are more advanced and potentially more efficient and cheaper biofuels under development which rely on two main processing routes to convert cellulose biomass into biofuels. First, the main bulk of advanced biofuels relies on a biomass gasification route. One gasification process produces synthetic gas, also known as syngas, which by means of a synthesis process can be converted to SNG, Fischer Tropsch diesel (FT diesel), Dimethyl Ether (DME) and methanol. This syngas may also be used to produce hydrogen. Another gasification process is known as thermal processing, such as Hydro Thermal Upgrading (HTU) and flash pyrolysis, for the production of bio oil or biodiesel. Second, cellulose ethanol is a very different, advanced biofuel processing route. It relies on a hydrolysis and/or an enzyme process which breaks down the cellulose feedstock to sugars, which in turn are fermented in a similar way as conventional ethanol (Royal Society, 2008).

Alcohols such as ethanol and methanol are most easily used in mixes with gasoline. A low-alcohol blend can be used without modification in gasoline engines, while the use of higher blends requires adjustments to engines. High blend ethanol/methanol vehicles with up to 85% ethanol and 15% gasoline are known as Flexi Fuel Vehicles (FFVs). For the use of bio oil, certain engine modifications are needed or a bio oil engine can be used, such as the Elsbett engine. Biodiesel is argued to have more or less the same properties as fossil diesel, which means it can be used as a blend in diesel or as a pure fuel in diesel engines manufactured previous to 2000 if the natural rubbers are changed to synthetic ones. For some time, German vehicle producers guaranteed use of pure biodiesel in specific vehicle models produced before 2006. For the use of biogas or SNG in engines, specific natural gas engines are needed. These have been in use for a long time in countries such as Italy. There are also so-called bi-fuel vehicles with a two-tank system: one for gasoline and the other for natural gas (Fuelswitch, 2012). Like gas fuels, the use of DME fuel requires a tailor made engine. However, unlike gas engines, this engine technology is new and has only been used on a small scale.

1.1. Conceptual and methodological approach

This section introduces the conceptual and methodological approaches in more detail. First, I outline and explain my choice of theoretical perspectives, SNM and the discourse theory. Second, I present the way in which I combine these perspectives in the conceptual scheme. Third, I outline the research question and sub questions. I close the section with a presentation of the method.

1.1.1. SNM

Transition theory

SNM is part of transition theory. Transition theory is a literature field that focuses on system innovations, also known as transitions, to overcome particularly persistent problems that pose a barrier to development towards a more sustainable society. These problems are persistent because they are firmly embedded in societal values and structures. This results in socio-economic-technological path dependencies or 'locked-in' development patterns, which are very difficult to alter. A transition towards more sustainable development patterns implies a radical shift at various levels of society. This involves innovation, implementation and use of new technology, which demands a cultural change of mindset and a variety of other legal, economic and social institutional adjustments necessary for societal embedding. Due to the all encompassing change that a transition implies, it is usually a long-term process stretching over 40-50 years (Grin, Rotmans & Schot, 2010). In this study, the persistent problem relates to the negative effects of fossil fuel use in the transport sector. The persistence of this problem is reflected in successive increases in fossil fuel use since the 1940s despite the identification of increasingly more negative effects. Examples of the latter are the dependence on imports from politically unstable oil producing countries, the fact that oil is a finite resource and that it has negative environmental effects of both local and global character (IEA, 2011; Kahn Ribeiro et al., 2007).

Several alternative technologies have had trouble breaking through due to dominant societal values and structures. The need for 'protection measures' to enable continued experimentation and learning about radical and sustainable innovations and potential systems change towards a more sustainable society is part not only of SNM theory but also of transition theory in general (Smith & Raven, 2012). In addition, the limited attention paid to protection is not unique to SNM, it also applies to the transition literature in general (Smith & Raven, 2012; Ulmanen et al., 2009). The choice of SNM for analysing transition dynamics, including protection-related policy dynamics to explain differences in Swedish and Dutch biofuel development, is linked to the fact that the niche concept is more central in SNM than other analytical perspectives in the transition literature. I outline below the SNM perspective, its background and the way it defines protection.

SNM perspective

In the transition literature, SNM is often contextualized from the Multi-Level-Perspective (MLP). The MLP is a three-level heuristic for analysing the dynamics of socio-technical transitions (see Figure 5). According to this perspective, processes within and between these three levels need to be aligned in order for a transition to come about. The three-level heuristic covers the analysis of regimes, niches and landscape processes. At the level of the regime, conventional and dominant socio-technical practices reside which provide structure and stability for technology development. The path dependencies created by the regime are particularly difficult to alter due to the societal embedding of regime rules (Geels & Schot, 2010). According to Geels (2004), there are three types of rules. The first refers to regulative rules such as formal laws, the second to more informal norms and values, and the third to cognition, relating to actors' sense-making (ibid.). At the niche level, various R&D and experimental activities result in potentially radical and sustainable socio-technical novelties that might challenge the regime. Due to threat from the dominant regime, these novelties can become clustered together by networks of actors in technology niches. Niches protect and facilitate the continued development of the radical technologies. However, in order to change a regime, landscape changes may be necessary in addition to niche creation. At the level of the landscape, slowly changing economic, political and ecological systems set a wider context in which regimes and niches are embedded. Changes at the landscape level can cause regime instability, creating opportunities for niches to break through and alter or even replace the regime (Geels & Schot, 2010; Raven, 2005).

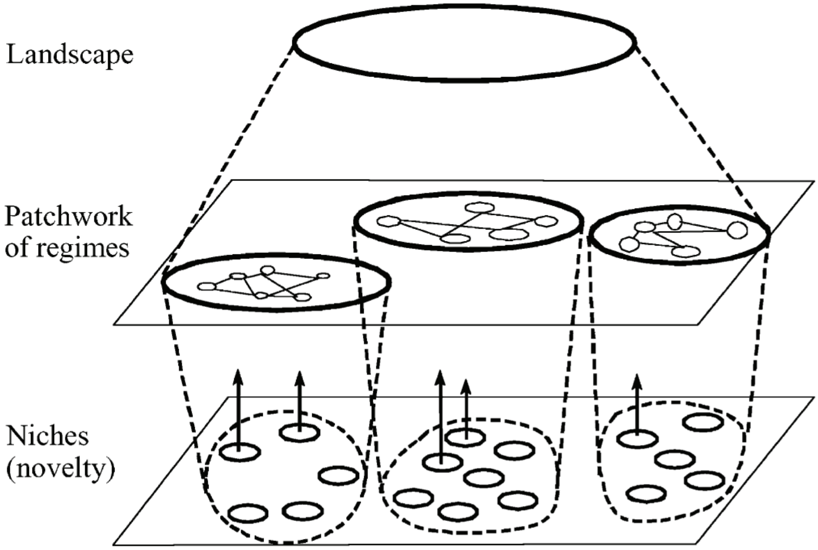

Figure 5: Three-level MLP heuristics
Source: Geels (2002:1261)

In contrast to the more general, transition perspective of the MLP, SNM focuses on activities at the niche level and the way in which niches are mobilized to overthrow an existing regime. According to Schot et al. (1996) and Schot and Geels (Schot & Geels, 2008), niche creation is an important strategy for enabling radical technology change because it allows for the co-evolution of technology, user practices and regulatory structures. The niche is a key concept in SNM that serves as a form of protection. Without protection, novel technologies are likely to be dismissed by the regime before their potential has been explored.

SNM sees three internal niche processes as key to the successful development of potentially radical and sustainable technologies. The first process relates to the voicing of *expectations* and promises related to a niche technology. Expectations guide technology development and particularly positive expectations attract resources and actors committed to development. The second process relates to the *network* of actors involved in the development of the technology niche through socio-technical experimentation, learning and the articulation of related expectations. A large number and variety of niche actors with aligned niche activities and beliefs, i.e. geared towards the same goal, is particularly positive for niche development. Studies have shown that the involvement of regime actors in particular has increased the chances of securing resources and of institutional embedding, and that the involvement of outsiders has been stimulating for the second-order learning part of the third niche process. The third niche process relates to the *learning* of the niche actors. Two types of learning – first- and second-order learning – have been identified as important for niche development. First-order learning relates to improvement of the design through experiments and communication with various actors, e.g. users, producers, governing actors, about their needs and demands. In second-order learning, the basic assumptions held about technology, user demands and regulations are not only tested but also questioned and explored. Second-order learning questions the regime, which is likely to lead to greater flexibility and openness to new and possibly radical technology solutions that might alter the regime. However, studies have shown that such learning does not come easily, but needs stimulation by particular drivers and contexts (Schot & Geels, 2008; Raven, 2006). According to SNM scholars (Hoogma et al., 2002; Raven, 2005; Geels & Schot, 2010), these three niche processes are interrelated, influencing each other and the direction of the technology development process.

The way in which niche internal processes emerge and contribute to a technology niche, stable market niche or regime is shown in Figure 6. It shows that a niche development starts with single projects driven by local networks. These projects will only form a niche if they start to communicate lessons and share expectations which in turn contribute to emergent rules. A process of feedback starts between the local project level and a more aggregated niche level, which determines the trajectory of the niche (Geels & Raven, 2006). This means that the success or failure of one project does not, as outlined in early SNM theory, determine the survival of the niche. Instead, it feeds into a common learning trajectory (Schot & Geels, 2008). An additional, more recent insight is that increased niche variety does not necessarily create better conditions for second-order learning and sustainable development. It may even hamper them due to the uncertainty this competition creates (Schot & Geels, 2008).

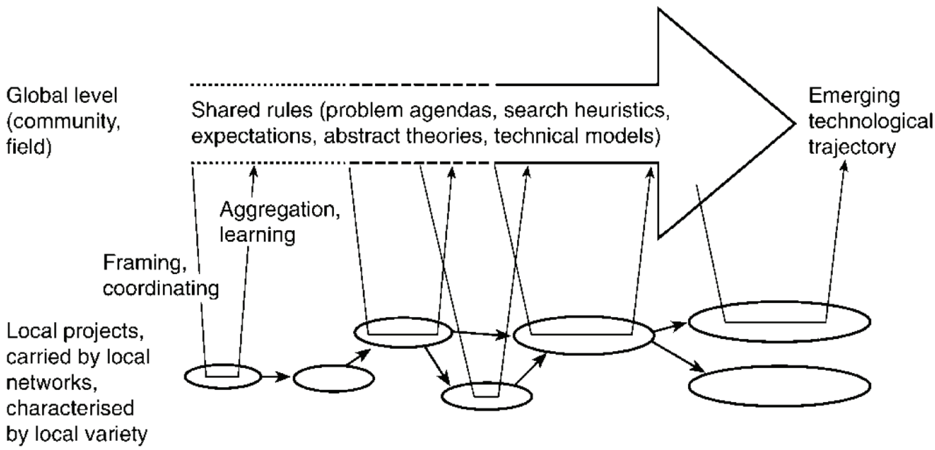

Figure 6: Emerging technical trajectory of local projects
Source: Geels and Raven (2006: 379)

Background

Both MLP and SNM stem from evolutionary economics and Science, Technology and Society (STS) studies. Quasi-evolutionary theory, founded by Rip (Rip, 1995) and Schot (Schot, 1992; Schot, 1998), is a forerunner to MLP and SNM[9] that did the initial work of bridging evolutionary economics and STS.

Both early evolutionary economics scholars (Nelson & Winter, 1977; Dosi, 1982) and STS scholars (Bijker, Hughes, & Pinch, 1987) examine socio-technical evolution and challenge conventional views about technology development.[10] The main finding from STS is that technology development is a complex process of negotiation, which moves back and forth between the science, market and the policy domains in a non-linear manner. Hence, according to STS, a variety of actors' beliefs and values are of great importance in shaping technology. Like STS scholars, evolutionary economists see actors' beliefs as central in shaping technology development. However, the early evolutionary economists saw actors' beliefs as routine-based, and thus also the resulting innovation process as more structured. From the evolutionary economic perspective, technology development is a result of a co-evolution between variation and selection. In the variation environment, engineers develop innovations, so-called product varieties, and in the selection environment the market selects the variety which is most desirable. The rigidity is visible in the concept of a 'technology regime',[11] which consists of the cognitive routines[12] of engineers who influence the direction of innovation. This state emerges when a product variation is selected repeatedly due to its popularity, and its design and related engineering routines are reproduced across an industrial sector. As a result of the cognitive nature of these routines, innovation follows an incremental development trajectory. Mistakes can still result in deviations from this trajectory, which implies that innovation cannot be predicted.

Quasi-evolutionary scholars (Rip, 1995; Rip & Kemp, 1996; Schot, 1998; Van den Belt & Rip, 1987) appreciated the agency of actors in STS and the structure in evolutionary economics and combined these perspectives in a similar way to Giddens in his structuration theory. In this way, the evolutionary economic idea of a technical regime steering engineers' routines at the firm level was translated into socio-technical regime rules governing wider societal sectors.[13] Hence, in contrast to the evolutionary economic idea of regime pressure on variation alone, quasi evolutionary scholars saw the influence of the regime on both the variation and selection environment. At the same time, the creativity and agency of actors was acknowledged, which implied that intentional radical innovation and action to change rules was made possible in the quasi evolutionary framework, which in turn was facilitated by protection in niches.

[9] The SNM management perspective has also been inspired by Constructive Technology Assessment scholars (Schot & Rip, 1997).

[10] Evolutionary economics scholars challenge conventional neoclassical economic thinking, seeing it as far too static, while STS challenges the neoclassical view of actors as inherently rational, and of innovation as a process that can be directed towards political goals. Evolutionary economics scholars see actions as steered by routines, and innovation as an inherently uncertain process of trial and error (Geels & Schot, 2010).

[11] Also known as a 'technology paradigm', according to Dosi (1982).

[12] In evolutionary economics, routines refer to sets of search heuristics, strategies and cognitive beliefs in the innovation process of a firm i.e., what engineers see as feasible in product development and problem-solving processes (Van den Belt & Rip, 1987 :137).

[13] These regime rules are similar to those outlined by Geels (2004).

While the MLP was developed as a historical analytical framework, the SNM perspective was developed to serve as both a management tool and an analytical tool of potentially sustainable technology development (Raven, 2005).

Protection

The MLP and SNM literature describe niche protection as the shielding of potentially radical technology from dominant rules, preferably until the dominant rules give way to new rules developed by niche actors.[14] While MLP defines general development patterns that can aid the shielding of a niche, e.g. landscape changes and weakening regimes, the SNM perspective treats the niche, and thus protection, as a core concept.

Some SNM literature (Hoogma, 2000; Hoogma et al., 2002; Weber, Hoogma, Lane & Schot, 1999) stresses shielding from the dominant selection environment, seeing market competition as the central problem. Other SNM literature (e.g. Raven, 2005: 31) is more attentive to the quasi-evolutionary argument that shielding from both variation and selection rules is necessary.

One way to shield niches is to implement them in an existing application domain where selection rules are less dominant, what is referred to as 'passive protection' by Smith and Raven (2012). According to the evolutionary economist Levinthal (1998) and some early SNM scholars (Kemp, Schot, & Hoogma, 1998:187; Weber et al., 1999:40; Hoogma et al., 2002:202), this can be done by using a specific market which is geographically remote or where idealistic users pay less attention to disadvantages. Smith and Raven (2012) give an example of the application of solar power as an energy generator in space in the 1960s as an example of geographic shielding. Geels' (Geels, 2005) study of the introduction of personal vehicles among actors with an interest in racing instead of conventional transport interests is an example of users who pay less attention to technology disadvantages.[15]

There are other niche protection measures, which Raven and Smith (2012) refer to as 'active' and which are more commonly referred to by the wider SNM community (Weber et al., 1999:40; Hoogma, 2000; Hoogma et al., 2002; Raven, 2005; Smith & Raven, 2012) as shielding through financial incentives or regulations executed by policymakers. These niche protection measures could include supply side measures to reduce the cost and poor performance of radical technologies (e.g. R&D funds, regulations, tariffs and taxes) or demand side measures aiming to alter preferences in the selection environment (e.g. quotas, public purchasing, information campaigns and market segmentation). Private actors use financial protection measures as well, in particular large industries use investment in product development. Such protection processes are frequently described by quasi-evolutionary

[14] That shielding is important for realizing transitions is recognized in the transition literature in general. One example is the Transition Management (TM) perspective, which also acknowledges multi-level dynamics and thus the need to shield the niche from the regime to enable development and potentially radical change (Rotmans et al., 2001). Another example is the Technology Innovation Systems (TIS) perspective. The TIS literature does not use the niche and protection concepts as explicitly as SNM scholars, but TIS scholars who study the development of potentially radical and sustainable technologies include shielding as part of the system functions and see it as a means to facilitate the development of innovations (Bergek, Jacobsson, Carlsson, Lindmark, & Rickne, 2008). Despite this recognition of shielding mechanisms, Smith and Raven (2012) argue that the TIS underplays the shielding mechanism since it does not fully account for the effects of regimes (Jacobsson & Lauber, 2006).

[15] Like SNM, the TIS perspective also has roots in evolutionary economics and refers to shielding through specific markets (Bergek et al., 2008; Jacobsson & Lauber, 2006). References to such shielding are also found in the TM literature (Rotmans et al., 2001).

scholars (Van den Belt & Rip, 1987; Rip & Kemp, 1996) analysing R&D niches within industries.[16]

Yet other protection types can be linked to the dynamics of niche internal processes. Quasi-evolutionary scholars point out that: 'Drawing on the expectations about the success of the heuristics [related to a radical innovation], influence is exerted on the selection environment and a niche is created that protects the trajectory against too harsh a selection' (Van den Belt & Rip, 1987:141). The central role of promises and expectations in generating protection can be traced back to evolutionary economists and is visible in the idea of paradigm shift, which they borrow from Kuhn: 'the success of a paradigm is at the start largely a promise of success' (Kuhn, 1970, quoted by Van den Belt & Rip, 1987:141).

Like the evolutionary scholars, SNM scholars recognize that expectations generate various shielding measures. According to Geels and Schot, the voicing of positive expectations and promises 'legitimate (continuing) protection and nurturing' of the niche technology (Geels & Schot, 2010:82). Similarly, Weber et al. (1999) and Hoogma (2000) describe the voicing of expectations and promises as strategic lobbying for protection.[17] In addition to expectations, the building of social networks also attracts protection in the form of resources such as money, knowhow and expertise (Geels & Schot, 2010:82). As is outlined in the SNM section above, voicing expectations and network building are interrelated processes that influence each other. In contrast to the evolutionary economic and quasi-evolutionary scholars' stress on expectations and promises as single driving forces for protection, SNM theory presents all three internal niche processes, voicing of expectations, network formation and learning processes, as interrelated. Positive feedbacks between niche processes nurture niche development within the protected space (Raven, 2005; Weber et al., 1999). An additional interpretation is that of Mourik and Raven (2006), who suggest that the creation of passive and/or active protection measures is necessary for niche nurturing and thus protection should also be defined as a niche process: '... the creation of protection is one of the four interrelated niche processes that determine the fate of the niche' (Mourik & Raven, 2006:29).

Scholars such as Raven (2005) and Smith and Raven (2012) describe these nurturing processes as having an additional, more indirect protection function. If successful, nurturing may result in stabilization and institutionalization of the niche. The latter reflects a state in which the technology niche evolves to a market niche with new rules – a so-called proto-regime – which has shielding functions, albeit limited in comparison to those of dominant regimes (Geels & Raven, 2006; Smith & Raven, 2012).

While niche stability and increased institutionalization could be defined as a type of protection, as shown above, SNM scholars (e.g. Kemp et al., 1998; Raven, 2005; Weber et al., 1999) generally speak of protection as temporary. The reason for this is the early definition of protection as either passive (e.g. distinct markets shielding the product) or active (e.g. financial incentives). Passive protection disappears automatically with market expansion while active protection needs to be phased out in order to avoid the negative consequences of protectionism. These negative consequences can include passive actors that no longer wish to

[16] Active protection, e.g. the use of financial and regulative measures to shield radical innovations, is also found in the TIS literature (Jacobsson & Lauber, 2006) and the TM literature (Rotmans et al., 2001; Loorbach & Rotmans, 2010).

[17] Weber et al. (1999) speak of lobbying for protection by connecting technology expectations to problems, while Hoogma (Hoogma, 2000) speaks of coupling expectations with ideographs, which are language terms referring to an abstract and normative collective goal widely shared in society, such as 'democracy', 'climate change' and 'technical progress'.

learn or critically evaluate technology qualities, which in turn leads to less sustainable technology outcomes. [18]

We end up with various shielding types. It is noteworthy that a specific shielding type matches a specific niche type. For instance, active shielding measures are mainly applied to technology niches, while passive shielding is applied to small market niches (see Geels & Raven, 2006). Protection through internal niche processes may apply to both technology and market niches, while protection through rules created by these processes demands a more stable market niche.

Despite the central role of protection in shielding the niche from dominant rules, there is still no clear definition of protection in the SNM literature. SNM and related evolutionary scholars present a variety of definitions of protection. Moreover, while mentioning the effect of expectations and promises as well as wider internal niche processes in attracting niche protection, such as resources and eventually stability, it is not totally clear how the various protection measures come about and interact with other niche processes. It is only recently that scholars (Smith & Raven, 2012) have made a first attempt to map these issues and discuss some of these questions at a theoretical level.[19]

1.1.2. The discourse perspective

Governance perspective in transition literature

In the early transition literature (Jacobsson & Bergek, 2004; Hoogma, 2000; Kemp et al., 1998; Rotmans, Kemp, & van Asselt, 2001), the government is seen as the main protector and manager of transitions. Later, however, the focus on the government is reduced (e.g. Loorbach, 2010; Loorbach & Rotmans, 2010). This is part of a general trend change from a focus on government to governance in political science. Contemporary political science literature points out that the policy process is not decided by the government alone in a simple and straightforward manner. It is a lengthy, non-linear and complex governance process that involves multiple interacting actors within the market, science and policy domains, who negotiate and use strategies to steer the political agenda in the direction of their interests (Grin, 2010; Voss & Kemp, 2006).

Transition scholars generally refer to public policy as the main source of financial and regulative protection (Hoogma, 2000; Raven, 2005; Jacobsson & Lauber, 2006; Jacobsson & Bergek, 2004; Rotmans et al., 2001; Loorbach & Rotmans, 2010).[20] In addition, without further explanation of how protection is created, many transition scholars have studied the policy process as a source of protection (e.g. Jacobsson & Lauber, 2006; Loorbach, 2007;

[18] Like evolutionary economic and quasi-evolutionary scholars, expectations and promises are highlighted as key to attracting shielding measures (Bergek et al., 2008; Jacobsson & Lauber, 2006; Jacobsson & Lauber, 2006; Bergek et al., 2008). According to Bergek et al. (2008), this is particularly true in the earliest stage of the formative phase when expectations of the innovation system are used strategically to gain legitimacy, i.e. certain social acceptance and compliance with relevant institutions. At a later stage, a variety of TIS elements contribute to legitimacy through institutionalization (Bergek et al., 2008; Jacobsson & Lauber, 2006). This TIS idea is, according to Smith and Raven (2012), comparable with the SNM idea of protection through the stability of a market niche which appears as a result of positive niche internal processes.

[19] A vague definition of protection and a lack of attention to how it comes about is also visible in other transition literature such as TM and TIS (Smith & Raven, 2012).

[20] This is also indicated in a comparative study of Dutch and Swedish biofuel development (Hillman et al., 2008) where policy incentives are presented as a main reason for differences in biofuel development (ibid.).

Avelino, 2011).[21] In fact, the management bias within a large part of the transition literature is reflected in a branch that studies governance processes. According to these scholars (Voss & Kemp, 2006), rigid governance patterns are not ideal for transitions. Instead, new and in particular systemic and reflexive modes of governance are thought to be necessary to stimulate transitions towards a more sustainable society. In line with the governance philosophy, this *reflexive governance* recognizes the multiple practices, interests and other more contextual developments that influence the policy process, making it nonlinear and highly unpredictable. Despite this complexity and uncertainty, one way to steer the policy process in a reflexive governance way is to use existing forces in society, i.e. mobilize key stakeholders,[22] to learn and reflect about contemporary and alternative problem definitions and the way they are managed in order to create a more sustainable society (Grin, 2006; Loorbach, 2007; Loorbach & Rotmans, 2010). Hence, transition scholars argue implicitly for the need to construct space for change on two levels in order for radical and potentially sustainable technologies to come about. First, at the societal level where innovation and implementation of the novel technology takes place. Second, at the policy level, among dominant actors and ideas, to enable new policies that successfully manage and shield the novel technology. I call this policy space the *policy domain*, a concept which Sabatier (1988) and Sabatier and Jenkins Smith (1999) define as 'actors from a variety of public and private organizations who are actively concerned with a policy problem or issue'. It is the development of the policy domain and its related policy outcomes that are of interest in this section. This leads us to ways in which political science, and discourse theory in particular, can aid our understanding of the policy process and its resulting shielding measures.

Analysing the policy process

Political science offers a multitude of perspectives for studying the process of policy change (Fischer, 2003; Sabatier, 1999). The majority of early theories focused on self-interest as a driver for policy and delivered positivistic casual explanations, such as stage-heuristics and other rational choice theories. Later theories use interpretative perspectives that focus on ideas as drivers of policy change, such as discourse analysis which delivers what Fischer calls quasi-casual explanations (Fischer, 2003). For the analysis of the policy process in this thesis, I have chosen a discourse perspective. A discourse analysis can be used to identify one or several discourses by tracing linguistic regularities in discussions or debates. By analysing the variety of actors that try to influence the direction of a debate and related discourses, insight is gained into why certain ideas or policies are accepted or rejected in a particular time and place (Hajer, 2003; Hajer & Versteeg, 2005).

Several arguments suggest the choice of an interpretative discourse perspective for my thesis. First, the discourse approach can be used in combination with the transition studies perspective since, according to Fischer (2003), it stems from the same postmodern tradition in social sciences, recognizing uncertainty and actors as not inherently rational. Second, the discourse approach is commonly used to analyse environmental politics (Kern, 2011:1119; Hajer & Versteeg, 2005) and has also been used by transition scholars (Kern, 2011;

---

21 Smith and Raven (2012) are exceptions who have explored this at the theoretical level. They refer to the political process creating legitimacy for the niche as 'empowerment', which is seen as contributing to shielding and nurturing measures. They argue that empowerment can be created in two different ways: fit and conform or stretch and transform. The fit and conform strategy implies that the niche is empowered to fit the existing system, making the niche innovation competitive with the regime. The resulting change is incremental. Stretch and transform implies that new niche rules are developed, which mature and replace the regime – resulting in radical change. From the perspective of transition theory, the latter is the aim.

22 These stakeholders are mobilized in what TM scholars call arenas (Loorbach, 2010; Loorbach & Rotmans, 2010).

Kern & Smith, 2009; Sengers, Raven, & Van Venrooij, 2010). Third, the discourse perspective is malleable and, unlike early rational choice perspectives, allows for the integration of other political science perspectives, such as interests and institutions, in a way which fits the purpose of this analysis. For instance, the perspective that actors are boundedly rational is used in transition theory and discourse theory. Bounded rationality implies that actors cannot have perfect information about issues in the world because their thoughts and interests are shaped by the beliefs, perspectives and ideas surrounding them (Fischer, 2003). This brings us to yet another factor affecting the policy process – institutions – which it is interesting to integrate into a discourse perspective used to analyse transitions. Some of the ideas and beliefs that influence actors are grouped together in discourses, other ideas and beliefs are part of less malleable institutions that constrain or create opportunities for the development of discourses (Fischer, 2003; Kern, 2011).

There is a great variety of discourse perspectives. My discourse analytical approach is pragmatic, and its sole ambition is to answer the questions posed in this research.

A discourse analytical perspective

A discourse is 'an ensemble of ideas, concepts and categories through which meaning is given to social and physical phenomena, and which is produced and reproduced through an identifiable set of practices' (Hajer, 2003:303; Hajer & Versteeg, 2005:175). Hajer's definition is particularly interesting since it puts discourses in close relation to what he calls 'practices', also known as institutions, or the various routines, rules and norms that give structure to social life (Hajer, 2003; Hajer & Versteeg, 2005). In a similar vein, other scholars connect discourses to belief systems (Sabatier, 1988) or cognitive frames (Schön & Rein, 1994; Fischer, 2003). Consequently, discourses shape people's perceptions of reality and their actions, including of the policy process and its outcomes (Hajer & Versteeg, 2005; Hajer, 2003; Hajer & Versteeg, 2005; Fischer, 2003; Phillips, Lawrence, & Hardy, 2004; Sabatier, 1988).

Different discourses have different powers of influence in society (Fischer, 2003; Hajer, 2003; Hajer & Versteeg, 2005; Phillips et al., 2004; Schön & Rein, 1994; Sabatier & Jenkins-Smith, 1999). Discourse power can be measured according to the level of discourse structuration and institutionalization. An increased number of actors supporting a discourse results in a higher level of discourse structuration. Discourses gain additional power if they become institutionalized in organizational practices, rules and norms. In the very highest form of discourse institutionalization, ways of reasoning appear to be traditional, natural or normal, or are even presented as social facts. Hence, when the discourse has both high structuration and institutionalization it is considered dominant and particularly difficult to change (Hajer, 2003; Hajer & Versteeg, 2005). Despite the structuration and institutionalization of discourses in various practices, rules and norms, however, they can change. Discourse change is dependent on activities internal and external to a discourse and related policy subsystem. External activities that can create opportunities for change are crises (e.g. financial, natural disasters, war) and political incidents (change in other policy domains or general governing coalitions) that undermine the institutional legitimacy of the dominant discourse (Hajer & Versteeg, 2005; Sabatier, 1988; Sabatier & Jenkins-Smith, 1999).

Alongside externally generated opportunities for discourse change, novel and alternative discourses need to be generated internally, within a policy subsystem, in order for change to come about. Novel discourses start out with a single actor wanting to convince others of his/her belief, idea or problem formulation. When other actors learn about this idea, they may choose to align in a coalition which lobbies for the same belief or idea (Hajer &

Versteeg, 2005; Sabatier, 1988; Sabatier & Jenkins-Smith, 1999).23 To gain wider legitimacy and support, these ideas or problems are usually translated into catchy one-liners, condensed statements or metaphors, also known as storylines (Hajer, 2003). Hajer (2003) argues that the different meanings that the storylines generate for different actors facilitate the acceptance and use of the storyline by others as well as the coupling of several storylines into the coherence of a discourse.

A variety of strategies can be applied by coalitions to gain recognition for a discourse or to keep it powerful. The strategies of coalition actors may involve adjusting, praising and defending their own storylines or discourse, or attacking, criticizing and ridiculing competing storylines and discourses (Hajer, 2003). This can be done by using particularly legitimate actors to give voice to the discourse, or refer to supportive expert statements and research findings (Hajer, 2003; Sabatier & Jenkins-Smith, 1999; Phillips et al., 2004). Reference may also be made to institutionalized and widely accepted discourses in order to improve the coherence of the various storylines in the discourse and gain additional support (Phillips et al., 2004). Other, usually less visible, strategies are pure manipulation and bribery. An additional strategy is to voice the discourse in particular venues of influence, e.g. for influencing public opinion. Mass media, boycotts and demonstrations may primarily be used to influence political actors, and lobbying various political offices such as administrative agencies, legislators or various political parties may be successful strategies (Sabatier & Jenkins-Smith, 1999). Sometimes, practical demonstrations of an idea may be used to better persuade actors of its benefits (Hajer, 2003). At other times, competition is so fierce that the competing coalitions are happy to settle for a compromise, which is occasionally mediated by third party, so-called policy-brokers (Sabatier & Jenkins-Smith, 1999).

Constant competition with and adjustments to other storylines mean that discourses, institutionalized practices and external events are in constant flux, and policy change is not simply a result of accepting a new idea. The emergent idea is constantly being modified in more or less strategic ways in order to gain acceptance, if possible, by a wider policy community. Once acceptance of one or several novel discourses increases, this results in new informal institutions involving cognitive rules, norms and values, as well as more formal policy programmes, regulations and standards (Hajer & Versteeg, 2005; Sabatier & Jenkins-Smith, 1999; Phillips et al., 2004). In turn, these institutions may limit or create opportunities for action and for the development of new discourses (Hajer, 2003; Phillips et al., 2004).

As a result of this review of selected discourse literature, I have a number of concepts through which to analyse the policy process. The core analytical concepts involve: first, the biofuel discourse or discourses and the backdrop of other related discourses and events influencing its development; and, second, the biofuel discourse coalition and the activities that it uses to maintain or increase the legitimacy and political influence of the discourse.

Despite the benefits of the discourse approach outlined above, it has also been criticized for its limitations. A general critique is that a discourse analysis of the policy process is not objective, but ideological in nature – implying that such an analysis is tainted by the political views of the analyst (Fischer, 2003). From a postmodern scientific perspective, this may be an equally large problem in any scientific approach. Moreover, in discourse studies a good scientific methodology is key to a high quality analysis. According to Fischer, a good discourse analyst aims to cover a variety of political views, particularly the neglected ones, to reveal both power relations and strategic rhetoric.

23 This coalition has several names in the discourse literature, such as 'discourse coalition' (Hajer, 2002; Hajer and Versteeg, 2006) and 'advocacy coalition' (Sabatier, 1988).

Another general critique is that language and ideas are not the only factors that dictate policy outcomes. For instance, material and financial resources also set limits on possible policy outcomes (Kern, 2010). I agree that this is a shortcoming, but argue that the discourse perspective is not totally blind to resource issues. If particular resources matter for decision-making they are unlikely to go unnoticed in the political debate. While resources are not the focus of this work, I reflect on general differences in national resources, particularly raw materials, as part of the conclusions of this thesis.

1.1.3. Conceptual scheme

The way in which the SNM framework and the discourse framework is applied in the conceptual scheme is outlined below, starting with the SNM perspective.

SNM analysis

The framework for carrying out the SNM analysis is outlined along six analytical categories in the columns on the first row in Table 1. These categories set out to capture biofuel niche evolution in Sweden and the Netherlands, based on the literature review on SNM above. Each category is used dynamically accounting for changes over time, and within the various time periods analysed.

Category one concerns the main actors in the niche network, involved in arranging and carrying out the experiment and how it changes over time. This category describes one of the three processes central for niche development in the SNM framework. Category two concerns the type of biofuel experiments carried out by the network and how they change over time. Category three concerns the evolution of the main expectations related to the biofuel experiments. This category covers a second niche process of the framework. The fourth category is set out to cover the main experiments - the most visible or the ones with the biggest impact – to set some examples for the niche developments. The fifth category focuses on the *lessons* drawn from these experiments by the network actors, which reflects the third and most central niche process in the framework. The result of the activities described in the categories, with a focus on the niche processes, adds up in the sixth category – the resulting *socio-technical configurations*. This is a concept developed by Rip (1995) and is in this context interpreted as visible technology developments, e.g. the number of biofuel vehicles and amount of infrastructure implemented, and the institutional elements coupled with this development, such as standards and regulations. [24]

As is outlined in the SNM section, SNM can be contextualized in an MLP analysis. In fact, the most common SNM practice is to analyse niche internal processes and related regimes and sometimes also the landscape. As is indicated in the conceptual scheme above, the SNM analysis focuses on the dynamics of niche internal processes alone while the discourse analysis indirectly covers some of the regime and landscape dynamics by describing the political forces facilitating or hampering policy protection.[25]

---

[24] The definition of socio-technological configuration may reflect what some SNM scholars define as a technology or market niche. As is outlined above, the niche also involves shielding elements not fully described in the column on socio-technical configurations. Example of the latter are shielding measures emanating from the policy process, which are part of the discourse analysis outlined in the lower column, Resulting space, of the conceptual scheme (see table 1).

[25] By using a discourse analysis of the policy process certain dominant views and institutions of the regime become visible. Discourse analyses will also give attention to external events that similar to landscape changes affect the dominant views and institutions and can create opportunities for niche development. Different from a regime analysis, a discourse analysis of the policy process will not reveal the technology processes of the dominant regime (variation and selection patterns) that hamper niche development.

SNM ANALYSIS	**Network actors** (main actors involved in experi-mentation)	**Biofuel** (type (s) experi-mented with)	**Expectations** (main biofuel expectations)	**Key experiments** (most visible or resulting in large impact)	**Learning** (lessons from experiments)		**Resulting socio-technical configurations** (infrastructure, institutions, market development, etc.)
DISCOURSE ANALYSIS	**Biofuel** (type that discourse referred to)	**Discourse** (main features)	**Wider discourses, events and policies** (which were mobilized or had an impact)	**Discourse coalition** (actors supporting the discourse)	**Target audience** (of coalition activities/ strategies)	**Key activities/ strategies** (of coalition to legitimize discourse)	**Resulting space** (policy creation or disruption)

Table 1: Conceptual scheme

Discourse analysis
The framework for carrying out the discourse analysis is outlined in seven categories in the columns on the second row of Table 1. The focus of the analytical categories is to capture the central elements of the biofuel discourses and their dynamics, in order to explain the development of policy-related niche protection in Sweden and the Netherlands. Like the SNM analysis, the categories of the discourse analysis are applied in a dynamic manner accounting for changes over time.

The first category concerns the *type of biofuel* that the discourse refers to. The second category describes the main features of the *biofuel discourse* and how it changes over time. A detailed description of storylines or distinction between storylines and discourses is not included in this work due to the general nature of the data, which span long time periods. The third category aims to capture external influences, such as societal events (e.g. change in governing bodies, socio-economic conditions and markets), and the context of *discourses* (e.g. environmental and fossil-fuel discourses) that affect opportunities for biofuel discourse development in negative or positive ways. The fourth category refers to the *discourse coalition*, i.e. the main actors that support and promote the biofuel discourse. The fifth category concerns the audience to which the discourse coalition directs its activities and the sixth category describes the *key activities or strategies* applied by the coalition actors. Through these activities, the coalition actors try to gain more followers and increased institutionalization of the discourse. The sixth and last category sums up the *resulting space or protection*, in terms of policy creation or disruption, that the activities carried out by discourse coalitions and external discourses result in.

SNM and discourse perspectives taken together
The conceptual scheme contributes knowledge about the evolution of the biofuel niche from an SNM perspective, describing innovation and implementation at the societal level, and from a discourse perspective, describing the policy process leading up to shielding or non-shielding policy outcomes. The scheme explains the development of socio-technical configurations and the policy space, which results in a more elaborate picture of biofuel niche evolution than a conventional SNM analysis. The theoretical ambition is to combine these analytical perspectives in order to shed light on the protection concept and contribute to the SNM and transition perspective in general. An additional, more explorative, element of this research is to look further into the relationship between the two analytical perspectives outlined in the conceptual scheme. In so doing, points of interaction between the conceptual frameworks can be identified, and the question of how the success of niche experiments relates to the success of discourses and the amount of protection given can be addressed. These explorative issues are elaborated on in the concluding section of this thesis.

1.1.4. Elaboration of research question

Based on the conceptual scheme involving SNM and discourse theory, the research question is divided into empirical sub-questions. All the questions address the development of biofuels in Sweden and the Netherlands in the period 1970-2010, as set out in the introduction.

Main question:

1. *How can we explain differences in biofuel niche development in Sweden and the Netherlands in the period 1970-2010?*

To be answered using SNM analysis:

A) How have the various niche processes contributed to system building in the Swedish and Dutch biofuel niches?
   a. Who are the main actors in the biofuel niche network(s)?
   b. Which are the main biofuel experiments?
   c. What are the main expectations related to the biofuel experiments?
   d. What lessons can be drawn from these experiments by the niche actors?
   e. What are the socio-technical configurations resulting from the niche activities defined by the above questions (a-d)?

To be answered using discourse analysis:

B) How has the co-evolution of biofuel discourse coalitions and wider societal events and discourses contributed to the creation of protection for the biofuel niche in Sweden and the Netherlands?
   a. What are the main features of the biofuel discourse(s)?
   b. What is the influence of other (dominant) discourses and external events on the biofuel discourse(s)?
   c. Who are the actors in the biofuel discourse coalition(s)?
   d. What are the key activities/strategies carried out by the biofuel discourse coalition(s)?
   e. What is the resulting space in terms of policy creation and disruption as a result of the activities outlined in the above questions (a-d)?

To be answered from both analytical perspectives:

C) How does the analysis inform the Strategic Niche Management framework?

This will be elaborated on in the conclusions.

1.1.5. Method

This research uses a case study approach. According to Yin (2003), a case study approach is preferable in a study where research questions are both explanatory and exploratory, and where uncontrollable and contemporary phenomena are being studied. Two case studies that differ in their recent historical development – on biofuel in the Swedish and Dutch transport sectors – have been chosen to investigate the explanatory and exploratory research questions outlined above. The difference in biofuel development and implementation between these cases is suitable for the explanatory research question and, because it is likely to increase the theoretical generalizability, the differences between and within these countries are suitable for investigation of the exploratory research question. While some differences can be explained by natural causes, such as differences in biomass resources, the differences in policy support measures and contexts between the cases and within the cases along the different time periods make them suitable for the exploratory research questions posed. This reasoning is strengthened by Yin (2003), who argues that it is necessary to combine results from multiple cases in order to strengthen the results through replication.

To strengthen the evidence collected on the case studies, multiple sources of data are used (Yin, 2003). Due to the historical nature of the research, the collection of material was focused on printed documents with both primary and secondary sources. The advantage of printed documents is that actors, dates and locations can be pinpointed relatively exactly, compared to what is usually the case in interview material where actors tend to forget such details. However, the material would still be subject to personal interpretation and manipulation by the author.

The printed documents used mainly relate to biofuels, but also cover closely related technologies (e.g. other (fossil) fuels, (bio)energy, vehicles and transport sector- related infrastructure) and socio-economic issues, to encompass the development of biofuel experiments and discourses as well as the wider contextual developments influencing these discourses. The data used cover a great variety of sources:

- Policy documents (bills, memorandums, directives) at the national and EU levels;
- Reports from research institutes, universities and consultancy firms;
- Articles from popular journals and newspapers;
- Articles from scientific journals;
- Books;
- Material from conferences and meetings, such as proceeding, minutes and slides;
- The Internet sites of government agencies, NGOs and other interest groups and companies;
- Statistics from national and international statistical offices.

Personal communications were the second-largest source of data. My informants were mainly experts or generalists in the field who could present an overview of biofuel policy and technology development processes, and provide a context for the various sources of literature gathered. I also interviewed actors involved in key biofuel projects in order to gain more detailed information. The interviews were semi-structured, generally involving long, planned conversations but sometimes shorter, more informal talks at conferences and meetings or in telephone calls complemented by e-mail communication. In the latter type of communication, questions were posed in a more direct and information-oriented manner. Informants were approached using the snowballing method, i.e., the names of other potentially interesting informants were generated through contact with informants. I received additional transcribed interview material from a colleague at Utrecht University, Roald Suurs, and a masters student at Eindhoven University of Technology, Gijs van der Meer, who have also been doing research on biofuel development in the Netherlands. A detailed list of informant interviews is attached as appendix A. Informant interviews result in highly subjective data. However, they have been a useful complement to the information gained from the printed material.

A third type of data has been collected by visiting biofuel projects and by attending biofuel expert meetings. This has been a means for me as a social scientist to gain more information regarding the technical components and workings of biofuels. This is particularly related to the complex processes of advanced biofuel technologies. To some extent these meetings also involved insight into political processes and grants at the national and European levels. For an outline of key projects and meetings visited, see appendix B.

1.1.6. Outline of the thesis

This book contains nine chapters. After this introductory chapter, the two biofuel case studies and related analyses are presented over a number of chapters according to defined time periods and from the two – SNM and discourse – analytical perspectives. The Dutch case study is presented in chapters 2, 3, 4 and 5 and the Swedish case study in chapters 6, 7 and 8. Chapter 9 contains concluding analysis and discussion.

The way in which the thesis is structured, in particular the empirical chapters which are presented and analysed according to two separate analytical perspectives, implies that the thesis can be read in different ways. First, the thesis can be read from beginning to end, in which case the reader will encounter some repetition since the SNM and discourse narratives on biofuel development have considerable overlap. Second, it can be read with a focus on either the SNM or the discourse story. Third, the reader may choose to read only the introduction chapter, the summarizing analytical sections at the end of each empirical chapter and the concluding chapter. Fourth, the reader can of course focus on different time periods or on particular biofuels of interest, as presented in the empirical chapters.

PART I: BIOFUEL DEVELOPMENT IN THE NETHERLANDS, 1990-2010

2. BACKGROUD TO DUTCH BIOFUEL DEVELOPMENT

2.1. INTRODUCTION TO THE CHAPTERS ON DUTCH BIOFUEL DEVELOPMENT

This chapter serves as an introduction to the Dutch biofuel case study. It sets the stage for Dutch biofuel development by presenting the context for alternative fuel and energy developments before and during the first biofuel developments, which took place in the 1990s.

Presentation of the Dutch biofuel development trajectory from 1990 to 2010 is in three chapters. Chapter 3 describes an emergent period (1990-1997), in which initial field experiments with conventional biofuels take place. Chapter 4 describes the period 1998-2002, indicating increased engagement in biofuel development. During this period, the first biofuel programme, GAVE, was started, but funds were only granted to advanced biofuel. Chapter 5 describes the third period, 2003-2008, in which large scale conventional biofuel market implementation takes place, stimulated by the EU biofuel directive.

The chapters each present two perspectives on the development of biofuels in the Netherlands. The first section presents a technology niche perspective, focused on entrepreneurial experiments leading to biofuel system building, which is analysed using an SNM framework. The second section presents a policy perspective, focused on the policy processes leading to biofuel protection measures, which are analysed by means of discourse theory. Each chapter closes with conclusions from both an SNM and a discourse perspective.

2.2. SETTING THE STAGE FOR DUTCH BIOFUEL DEVELOPMENT

This section presents the various technological and contextual developments of relevance to the Dutch biofuel development trajectory: first, early biofuel use during the Second World War; second, the development of the first modern alternative fuel, Liquefied Petroleum Gas (LPG); and, third, the development of bioenergy, which could be seen as paving the way for the first modern biofuel experiments.

2.2.1. Biofuel as an emergency fuel during the Second World War

During the Second World War, a small amount of biofuel in the form of generatorgas produced by gasifiers hung on the back of conventional vehicles substituted for fossil transport fuels.[26] However, this technology was mainly used by the occupying forces, which controlled all motorized vehicles (Klemann, 2002). After the war, the introduction of cheap and easily accessible transport fuels such as gasoline and diesel contributed to the disappearance of generator gas (Raven & Verbong, 2001). According to De Jong (1994), contributory reasons were the poor functioning of generator gas and its association with the occupying forces.

2.2.2. LPG: the main Dutch alternative fuel

Since generator gas was mainly used by the occupying forces, LPG could be seen as the first alternative fuel to gain ground in Dutch society (see Figure 7). According to De Jong (1994), fuel traders introduced LPG, in collaboration with US vehicle technology, into the Dutch heavy vehicle market in 1954. The fuel made a breakthrough in 1956, triggering interest from large petrochemical companies which stimulated market expansion still further. The successful introduction was a result of the huge demand for heavy vehicles after the war and the relatively cheap alternative that LPG provided in comparison with gasoline and diesel. The Suez crisis in 1956, which resulted in the rationing of all motor fuels except LPG, led to additional market implementation (ibid.). Figure 7 indicates continued growth in gasoline and diesel consumption, despite the rationing in the mid-1950s. In fact, the figure shows a positive trend along the whole timeline, with an exception for the 1970s and 1980s when gasoline consumption in particular stopped expanding and temporarily showed negative development patterns. The period from the early 1970s to the early 1980s shows increased growth in market share for LPG. According to De Jong (1994), this was due to the oil crises of 1973 and 1979, but also the internationally renowned report 'Limits to Growth' published in 1972. This report warned about the exhaustion of resources, particularly oil, and the negative effects of fossil fuel emissions on the environment and human health. In comparison with gasoline and diesel, LPG was argued to be a more abundant and less environmentally damaging alternative.

The growth in LPG market share stagnated after 1981. A contributory reason was that the price difference between LPG and conventional fossil fuels decreased with the normalization of the oil price. Other reasons were the cost of the LPG vehicle technology, which became higher than that of conventional vehicles, and that LPG technology became increasingly associated with a high risk of explosion (De Jong, 1994).

[26] Biomass in the form of wood was only one feedstock used for the production of generator gas in the portable gasifiers. The main feedstock was coal since it was more accessible (Klemann, 2002).

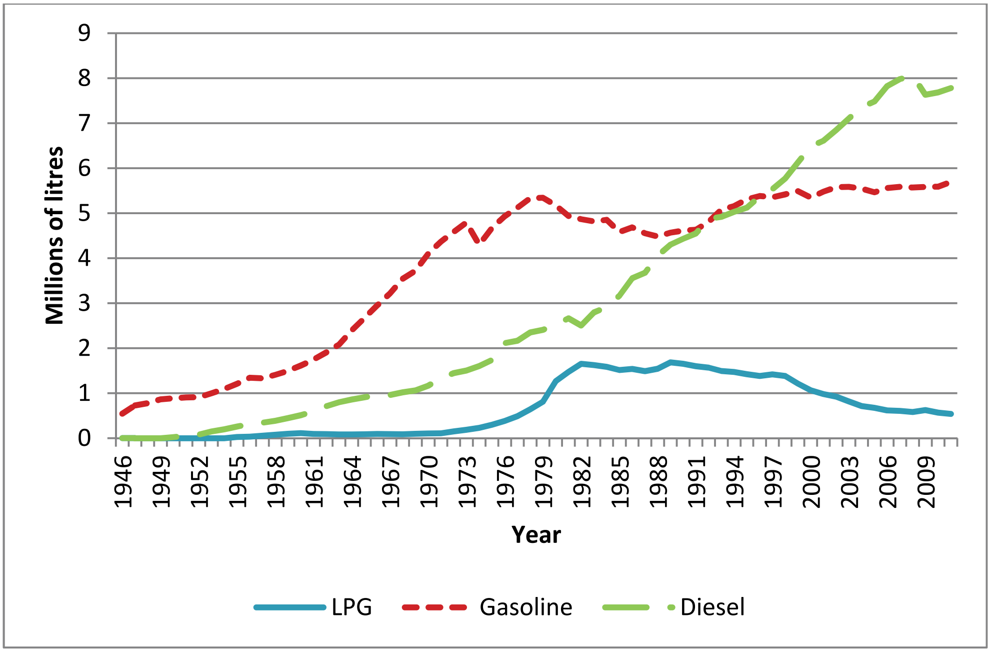

Figure 7: Deliveries of mineral oil products in the Dutch transport sector, 1946-2011*
Source: Statistics Netherlands
* The numbers for 2011 are tentative

According to Figure 7, LPG sales started to decline in the 1990s. Nevertheless, the fuel did not disappear entirely and there are signs of stabilization in 2007-2010. According to European Union (EU) statistics (AEGPL, 2010), the Netherlands has had the third-largest LPG market in Europe after Poland and Italy in recent years. The strong coalition of petrochemical companies in the Netherlands, with their major refineries in Rotterdam Harbour supplying the European market, can partly explain why LPG has survived this long in the Netherlands. The refineries produce a waste product that is a suitable feedstock for LPG production. LPG therefore fits well with the interests of the petrochemical industry.

Apart from LPG, no other alternative fuel options entered the transport sector before the 1990s. Another alternative transport fuel that could have been introduced at an early stage is natural gas, as a consequence of the large natural gas reserves discovered particularly in the late 1950s and the 1960s (Correljé & Verbong, 2004). According to the historical overview by Correljé and Verbong, natural gas resources were to a large extent in the hands of the large petrochemical industry, Shell and Esso (currently Exxon), which together with the government and other actors decided that the gas should be sold on the heat and energy market (Correljé & Verbong, 2004). It was not until the post-2000 period that Dutch actors started to consider natural gas as a potential alternative fuel for the transport sector, and then more as a potential bridging technology to biogas produced by means of gasification or anaerobic digestion (Wempe, Jepma, Hoogma, & Dumont, 2007). Due to the late and limited development of this fuel option, I have excluded it from this study.

2.2.3. Bioenergy developments: paving the way for initial biofuel experiments

At an initial stage, biomass for large-scale sustainable energy production, more commonly known as bioenergy,[27] stimulated the idea of using biofuels in the transport sector.

The interest in bioenergy in 1970s energy policy was reflected in the interest in energy production from waste that could contribute to oil substitution and the environmental goals emanating from the 1970s oil crisis and the 1972 Club of Rome report (Verbong & Van Selm, 2001; Raven & Verbong, 2001). Despite this policy interest, funds were scarce and there were only a few industrial bioenergy initiatives on waste combustion and anaerobic digestion in the 1970s. The 1980s produced a few initiatives on anaerobic digestion in the agricultural sector (Raven & Verbong, 2001).

A negative view of energy cropping hampered biofuel development. Policymakers rejected energy cropping based on the argument of limited agricultural space in the Netherlands and the potential competition with food. However, the use of biomass waste for bioenergy and biofuels was considered legitimate, which led to the start of an advanced biofuel project on Hydro Thermal Upgrading (HTU) at the Shell laboratory in 1983. The HTU process was similar to the refinery process, but wet waste biomass was used instead of oil. The result was an oil-like product called 'biocrude', which Shell saw as a promising raw material for vehicle fuel production. However, in 1988 Shell decided to terminate the project because of the stabilization of a low oil price in the mid-1980s (EET, 2001).

The stability of the low oil price also contributed to a radical decline in investments in alternative energy technology and the termination of ongoing projects, including bioenergy projects (Lysen et al., 1992; Raven & Verbong, 2001; EET, 2001). A complementary reason was arguably the increase in neoliberal political ideas at the time, such as 'Reaganomics' and 'Thatcherism' (Eindhoven University of Technology, personal communication, 01.15.2007)(Van de Wiel, 2006). However, interest in bioenergy from waste returned at the end of the 1980s. This time it was stimulated by increased environmental concerns related to the effects of emissions on the ozone layer and the climate, expressed by among others the United Nations in its report 'Our Common Future', also called the Brundtland report, in 1987 (Raven & Verbong, 2001). The latter resulted in a government energy policy, reserving NLG 5 million for the first bioenergy-oriented R&D programme 'Energy extraction from Waste and Biomass' (Energiewinning uit Afval en Biomassa, EWAB) which started in 1989. The focus of the programme was on combustion until 1995, and post-1995 on gasification (Raven & Verbong, 2001).

From a biofuel development perspective, the development of gasification technology is especially interesting. One of the greatest deliverables of the EWAB was a pilot gasifier constructed by the Energy Research Centre of the Netherlands (ECN) and a related actor network. The pilot was ready for use in 1997 and therefore the first gasifier in the Netherlands. In addition to ECN, a number of different gasification projects were set up in the north of the Netherlands. However, the withdrawal of core actors from the project, the electricity producers UNA and Sep, led to its termination in August 1998. The electricity producers explained their withdrawal by referring to the increased scarcity of biomass, which made expected electricity production costs by means of a gasification plant too high (Raven & Verbong, 2001). This triggered an interest in energy cropping (mainly cellulose crops) among bioenergy gasification actors, which opened up opportunities for biofuels (see chapter 3).

[27] In this thesis, bioenergy refers to the large-scale use of biomass for sustainable energy production. In this sense, bioenergy differs from the traditional practice of burning wood for heat and energy.

In fact, the agricultural sector's interest in energy cropping had emerged much earlier. In the late 1980s, increasing agricultural surpluses appeared in Europe because the EU Common Agricultural Policy (CAP) was overcompensating European farmers. To resolve this problem, the EU decided to revise the CAP in 1992. The new policy meant that farmers had to set aside 10% of their agricultural land. The EU compensated for the financial loss with other subsidies. One example of these subsidies was a grant to farmers who grew energy crops on the set-aside land (Raven & Verbong, 2001). The EU allowed for additional compensation by giving member states the power to grant temporary tax exemptions for the cultivation of energy crops from 1994 (Persson & Åsbrink, 1997). The Dutch response to the problems in the agricultural sector was to set up an Agrification movement and a related policy in the 1980s, with the aim of increasing the competitiveness of the agricultural sector (Knip, 1992). Both EU and Dutch policy changes contributed to the start of biofuel experiments in the Netherlands in the 1990s, as is described in chapter 3.

2.2.4. Concluding remarks

The difficulty of biofuel development in this period may seem surprising at first, given the oil crises and interest in alternative energy and fuels. However, this chapter indicates the various factors that are likely to have discouraged biofuel entrepreneurs. One main reason was the strong preference for waste biomass and opposition to energy crops, which is the main feedstock for conventional biofuels. In addition, the fact that an alternative fuel technology, LPG, had become institutionalized in the fuel market in the 1950s made it particularly difficult for less mature and more expensive biofuel alternatives to enter the market. However, environmental concerns, Agrification concerns and agricultural policy changes seemed to be opening up opportunities for biofuel development in the 1990s.

3. THE START OF DUTCH BIOFUEL EXPERIMENTS, 1990-1997

This chapter describes the development of biofuels in the period 1990-1997. I present the development of the biofuel niche, followed by an SNM analysis. I then describe the political processes that resulted in the development of biofuel policy, followed by a discourse analysis.

3.1. AN EMERGENT BIOFUEL NICHE, 1990-1997

As is outlined in chapter 2, there was only one dedicated biofuel experiment before the 1990s, based on HTU technology. This section covers the period in which both conventional and advanced biofuel initiatives started to emerge with government support, albeit only to a limited extent.

3.1.1. Conventional biofuels

In line with the intentions of Dutch Agrification policy, two sugar producing farmer cooperatives, Cosun and CSM, and an alcohol producing company, Nedalco, set up an organization, Development of Bio-ethanol from Agricultural raw materials (OBL), in the late 1980s. Together with a public transport company, Gado, which was owned by Groningen municipality, plans were set for a trial of ethanol in buses. To enable the trial, the actors began lobbying for a tax exemption in 1990 (Gelderlander, 1996; Van der Veen, 2003). Gado's wish was to run three buses, with slightly adjusted diesel engines, on ethanol. In addition to the support gained from the sugar cooperatives and Nedalco, which produced the fuel from molasses, other partners in the project were the Agricultural Board of Groningen, the research institute, TNO, which contributed scientific expertise and evaluations, and Mercedes, which provided technical support (NRC, 1991b; NRC, 1991a). The Dutch ministries of Agriculture (LVN) and Housing, Spatial Planning and the Environment (VROM) agreed the request for a tax exemption for the three buses, and the trial began in 1992 (Wiepkema, 1999). That the tax exemption took effect in 1992 is likely to relate to the EU directive granting tax exemptions in the same year.

The ethanol project suffered from repeated fires in the engines and complaints about an invasive ethanol smell. Nonetheless, when the trial ended in 1995 both Gado and TNO were pleased with the results. Gado claimed that technology improvements would lead to more CO_2 reductions and a reduction in the smell. TNO, which carried out a study on ethanol at the time, claimed that the Netherlands would be able to produce enough ethanol to run all the buses in the public transport sector (Wiepkema, 1999). However, once the tax exemption ceased, the price of ethanol was regarded as too high to keep the project running (Gelderlander, 1996; Parool, 1996).

There were different expectations of the project. According to Clevering, the former chair of Cosun, the parent company of Suiker Unie and Nedalco, the ethanol experiment was a way to support the economic position of the farmers who were part of the sugar cooperative (Van der Veen, 2003). However, De Nie (1992), the vice chair of OBL, argued that the reason behind the trial was not to aid farmers, but to aid the environment by reducing CO_2 emissions and smog, and substitute the use of lead as an octane booster with ethanol. De Nie's response could be explained by growing environmental concerns as a result of the Brundtland report (Brundtland, 1987) and the UN Framework Convention on Climate

Change in Rio de Janeiro which led to targets for stabilizing the level of CO_2 in the atmosphere to 1990 levels by the year 2000 (IPCC, 2004).

As the Gado trial proceeded, the sugar industry started to plan for an ethanol production plant at Nedalco. To be able to finance the plant and its relatively expensive ethanol production, they lobbied for a long-term tax exemption (Zoethout, 1997; Pols, 1996). [Once granted a tax exemption for a ten-year period, Nedalco and the related sugar cooperatives promised to set up a pilot that would produce 30 million litres of Ethyl Tert-Butyl Ether (ETBE) annually. ETBE is a bio-based gasoline fuel additive that was attracting interest at the time. Contemporary scientific studies showed that ETBE was an environmentally friendly substitute for the gasoline additive Methyl Tert-Butyl Ether (MTBE), used to raise the octane level of gasoline. Researchers argued that ETBE was an equally efficient octane improver, while at the same time reducing CO_2 emissions as a result of the substitution of the fossil components in MTBE and reducing the use of the toxic lead (Van den Heuvel & Kwant, 1996). In addition to Nedalco, actors such as the chemical company, Lyondell, and Shell were willing to cooperate in bringing ETBE on to the market (Nedalco, personal communication, 18.10.2005) . The central goals of the Nedalco project were threefold. First, the project aimed to show that large-scale production of ethanol was possible. The idea was that large-scale ethanol production would first be based on starch using conventional technology, which would be replaced by more advanced, new technology processing cellulose-based ethanol within a couple of years. Second, the project aimed to show that the use of novel cellulose-based technologies would reduce energy use in the ethanol production process by 45%. The third aim was to show that this new technology would reduce the cost of ethanol to 0.18–0.27 €/litre when the profits from by-products were included (Van den Heuvel & Kwant, 1996). Hence, the promise was not only to scale-up conventional ethanol production, but also to develop and demonstrate a novel production technology based on cellulose feedstock. According to Nedalco, cellulose ethanol was much more energy and cost efficient, which implied larger CO_2 reductions for a lower price. Furthermore, Nedalco made general promises in connection with these technology specific promises. In an article by Pols (1996), Nedalco argued that, if the government gave financial aid to enable the realization of the project, it would prevent general environmental degradation and the economic degradation of the agricultural industry.

Eventually, in April 1997, the Minister of Finance agreed to the first long-term tax exemption for ethanol (Van Miltenburg, 1997). For Nedalco this meant a remarkably large tax exemption of € 61.3 million, which could be used over a maximum period of 10 years, as well as a subsidy of € 6.8 million to build the test plant and advance ethanol process technology (Van Miltenburg, 1997; EVN, 1998). Nedalco's own investment was projected to be € 18.2 million (Stem, 1998). Although the government announced the tax exemption in April 1997, Nedalco had to wait until the next year for final permission to start the trial (Stegenga, 1999). This was primarily due to the need to get consent from the EU for the exceptionally large and long-term tax exemption (Didde, 1997).

In addition to the ethanol initiative, other actors also saw opportunities linked to producing biofuels as a result of the Agrification policy. While sugar beet farmers had an official platform in the 1980s, the first attempt to set up a biodiesel network was made by rapeseed farmers in 1990 (Buddingh, 1991; Van der Veen, 2003). The first campaign for biodiesel was organized by the farmers' organization, Cebeco Handelsraad, in 1992. In this campaign, representatives of farmers' organizations, such as the Cebeco Handelsraad, Groninger Maatschappij van Landbouw, Agricultural and Environment and Groninger Christelijke Boeren-en Tuindersbond, filled their cars with biodiesel outside the entrance of the headquarters of

Groningen Provincial government. One aim of the campaign was to demonstrate that driving vehicles on biodiesel was possible. However, more importantly, the aim was to gain tax exemptions from the EU to facilitate further research on a variety of oil seeds and to get subsidies from the national government for the construction of a test plant for biodiesel production (AD, 1992a). This campaign seems to have failed because no results were reported and trials in the early 1990s were related to neither pure vegetable oil (PVO) nor biodiesel production, and were not led by farmers' organizations. Instead, entrepreneurs and municipalities were the prime movers in the PVO and biodiesel field. This, however, does not rule out the possibility that the demonstrations by the farmers' organizations stimulated these prime movers.

The first entrepreneur to take the initiative in the PVO field was Moeken and his company Moeken's Montage in Groningen. In 1990, he set out plans for the production of Elsbett engines for use in boats and road vehicles. Elsbett engines are engines specified for PVO use. Moeken's business idea was inspired by positive experiences with Elsbett engines in Germany. The mayor of Veendam, a city in the Province of Groningen where Moeken intended to set up the production facility, was also highly positive about the initiative. The mayor was particularly enthusiastic about the environmental product and the new employment opportunities that the factory was expected to bring. These positive expectations meant that production licences were arranged and test engines were shipped to Moeken by Elsbett Konstruction (Elko) in Hilpoltstein, Germany, with a value of € 1.27 million. Moeken planned to cover 75 % of the cost of investment in the production facility, while the Province of Groningen and the Northern Development Association (NOM)[28] would cover the remaining 25% (NRC, 1990). However, at the last moment, the Province and NOM withdrew from the project arguing that Moeken's business plan was incomplete (NRC, 1991c). In what sense the business plan was incomplete has not been reported. However, Moeken's project was discontinued due to bankruptcy (Knip, 1991; AD, 1992b).

While entrepreneurs abandoned PVO technology, interest in biodiesel returned. In 1993, the Rotterdam public transport company (RET) ran three buses and a train on biodiesel for a couple of months. The vehicle producer, Volvo, and the fuel producer, Novamont, were part of the project. Rotterdam based its choice of biodiesel from rapeseed on the assumption that it would produce fewer emissions and less soot. To test if this was the case, the research institute, TNO, agreed to measure emissions such as sulphur dioxide and soot, but also CO_2 emissions (NRC, 1992a; Suurs & Hekkert, 2005a). The Municipality of Rotterdam is likely to have covered the costs, given that the municipality owned RET. To be able to extend the trial for a longer period, Rotterdam applied for funding from the EU Thermie programme. In early 1994, Rotterdam was granted € 1,3 million from the EU. Part of this grant was destined to fund a nine-year trial involving two or three hybrid electric buses and 29 biodiesel buses (ANP, 1994). Nevertheless, in the end, only nine of RET's city buses ran on biodiesel for a period of one year (BD, 1995). Although the biodiesel trial ran successfully, the partners did not consider it economically viable to continue the trials without external funds. As a result, the city of Rotterdam gave up biodiesel and terminated the project in 1995 (Suurs & Hekkert, 2005a). However, Rotterdam municipality would not give up on its interest in renewable fuel options (see below).

As Rotterdam terminated its trial, a new biodiesel initiative emerged. Two boat rental companies, Roukema from Irnsum and Holiday Boatin' from Sneek in Friesland, decided to start using biodiesel to fuel their boats. The main reason for this experiment was the

[28] Investerings en ontwikkelings maatschappij voor Noord Nederland (NOM) is a government organization that aims to stimulate employment and economic growth in the north of the Netherlands.

increasingly stringent environmental legislation on surface water pollution that emerged in the 1990s. The boating companies argued that biodiesel, unlike fossil fuel diesel, was biodegradable and could be used as a means to comply with the more stringent environmental standards. Another factor that influenced the choice of biodiesel was the close relationship between the boating companies and the oil distributor, Oliehandel Wiersma & Zn., which had experience with importing and using biodiesel (Van der Laak et al., 2007).

The first attempt to obtain funding for the project – from the EU – failed. At the second attempt, the project group requested a tax exemption from the Ministry of Finance (Trouw, 1995). This time, the Agricultural board of Friesland and the Province of Friesland supported the activities of the boating companies. They saw the use of biodiesel as an opportunity for farmers to gain an additional market for rapeseed production (FD, 1995). The project team requested a tax exemption for 500 000 litres of biodiesel for a period of ten years. After negotiations, the Ministry of Finance granted a two-year exemption on 90 000 litres of biodiesel for applications in water sport (Van Miltenburg, 1995). The trial started in June 1995, involving 70 boats in total from Holiday Boatin' in Sneek and Roukema in Irnsum (ANP, 1995).

The tax exemption led eight other boating companies to take an interest in starting similar biodiesel projects (ANP, 1995). Three of them began additional trials with biodiesel in boats in 1996 (Evers, 1997). In the first, the Province of Friesland contributed its own fleet of seven ships (Evers, 1998). This seems a natural step, given that the province joined the biodiesel network at an early stage. Second, the companies Kooij and Plas, which ran waterbuses in Amsterdam for the tourist industry, set up a trial involving two boats in 1996. The success of the project led the Amsterdam companies to extend it to six waterbuses out of the 30 that were running in 1997. Like the boating companies in Friesland, the main motive of Kooij en Plas was to meet increasingly stringent environmental standards. The municipality of Amsterdam, which set these local standards, suggested electric propulsion as a means to reduce the heavy fossil diesel emissions. However, Kooij and Plas considered electric engines not powerful enough, and chose biodiesel to maintain similar levels of power and manoeuvrability (Trouw, 1997). The Ministry of Waterways and Public Works (Rijkswaterstaat) carried out the third and final trial with a ship making measurements on the Wadden Sea (Evers, 1997). These experiments continued in the period 1998-2002.

3.1.2. Advanced biofuels

As is outlined above, the production of ethanol from cellulose materials was becoming more promising. Nedalco, supported by the sugar industry, lobbied to gain funding for a conventional ethanol production plant, in combination with cellulose ethanol R&D and the development of a pilot plant in the future.

As in the case of cellulose ethanol, this period showed increased interest in novel biodiesel technologies based on woody feedstock. However, experimentation had already begun in the advanced PVO field. Some of these experiments had started before the 1990s, generally in close cooperation with researchers in the field of biomass to energy. The promise in this field related to thermal processes converting dry biomass through pyrolysis to pyrolysis oil, or wet biomass using the HTU process to liquid oil (Okken, 1989; EET, 2001).

Pyrolysis is a process in which biomass is thermally heated (up to 900º C) without the presence of oxygen. The result is pyrolysis gas, pyrolysis oil, coal, ashes and water residues. Pyrolysis is an old technology used for wood distillation, a technique used when producing methanol, and for the preparation of charcoal and gas for household use. Scientists tried use the pyrolysis process in the 1970s and 1980s to get rid of household waste in a cheap and efficient manner (Van Rutten, 1987). In the late 1980s, extracting gas and oil via pyrolysis became more popular when scientists promoted it as a potential practice for the production of renewable and sustainable electricity, heat and motor fuels (Okken, 1989). The increasing promise of the technology in the EU led the Biomass Technology Group (BTG), linked to the University of Twente in the Netherlands, to seek to develop the technology further (Okken, 1989; BTG, 2006). BTG managed to develop a more efficient pyrolysis process, 'the rotating flash pyrolysis'. In 1994 and 1995, BTG managed to obtain funding from the UN FAO to carry out a laboratory trial on this technology together with Royal Schelde, a company working for the Dutch navy. This supported the expectations for the technology, which resulted in additional funds from VROM from its R&D programme for the development of energy production from waste and biomass, EWAB, and from subsidy programmes at the EU level. This led to the construction of a bench scale reactor in 1997. The funding from the EWAB programme was continued until 1999 and the EU programme until 2000 (BTG, 2006). Despite the increasing expectations and funding throughout the 1990s, the corrosive character of the oil remained a severe bottleneck. This was particularly problematic for the use of pyrolysis oil in engines (DE, 1996). Consequently, the prospects for pyrolysis oil as an automobile fuel declined rapidly in the late 1990s. However, pyrolysis technology enjoyed continued support in the field of heat and energy production (Raven & Verbong, 2001).

The final technology that attracted attention in this period was HTU based on wet biomass waste materials. As is explained above, it emerged as a project at Shell in 1983, stimulated by the oil crisis, but disappeared in 1988 when the fossil fuel market stabilized (EET, 2001). Two former Shell engineers, Jaap Naber and Frans Goudriaan, who had been experimenting with HTU fuel in the 1980s, did not give up their belief in the technology when Shell abandoned it. Naber and Goudriaan started a new company, Biofuel B.V., and began lobbying for funds (FD, 2001). The increased attention on the problem of Climate Change that emerged in the early 1990s offered ample opportunities for funding to continue HTU technology development. In a feasibility study published in 1995, Naber and others argued that HTU had clear cost and environmental advantages compared to other biofuel options, and that large scale implementation of HTU could make it competitive with fossil fuels by 2020 (Naber & et al., 1999). Other advantages were that biocrude could be used either as fuel for electricity generation or if upgraded as biofuel for the transport sector (EVN, 1996). A detailed R&D plan followed, which included commercial implementation of the technology as well as a business plan for the years thereafter. The growing promise of HTU technology attracted additional partners to the project, such as Stork Engineers and Contractors (currently Jacobs Comprimo Nederland), which provided technical services and equipment to the petrochemical industry, the research institutes, TNO-MEP and BTG, and Shell, which decided to support the project once more (Naber & et.al., 1999). Through the subsidy programme Economics, Ecology and Technology (EET), jointly administered by the Ministry of Economic Affairs, Ministry of Housing, Spatial Planning and the Environment and the Ministry of Education, Biofuels B.V. obtained a subsidy of NLG 11 million to set up a test installation with the aim of developing a design suitable for a larger demonstration project and eventually commercial HTU installations. The R&D project commenced in November 1997 (Naber et.al., 1999; DE, 1999).

3.1.3. SNM analysis, 1990-1997

Biofuels	1990	1991	1992	1993	1994	1995	1996	1997
Field trials								
Ethanol			OBL-Gado buses 3					
Biodiesel				RET buses 3		9		
				RET train				
						H & R boats 70		
							Friesland boats 7	
							K& P boats 2	6
R&D								
Pyrolysis					BTG			
HTU								Biofuels B.V.

Table 2: Conventional and advanced biofuel experiments, 1990-1997

Conventional biofuels

Ethanol

Network actors	Biofuel	Expectations	Key experiments	Learning	Socio-technical configurations
Sugar producing farmer organi-zations, Alcohol producer Nedalco and public transport company Gado.	Ethanol, pure use.	Business opportunity for farmers and alcohol industry due to reduced local and global emissions through local feedstock cultivation, production and use.	Trial with three public transport buses.	Despite minor initial problems, ethanol in vehicles works, evaluations show viability of ethanol production	Isolated experiment that survived as long as tax exemptions were in place. Industrial actors direct efforts towards construction of plant for which grant and tax exemptions were gained at the end of the period.

The two sugar producing farmers' organizations and Nedalco collaborating within OBL and the Groningen municipality transport company, Gado, were the main *actors* initiating a very small bus trial in this period. Nedalco provided the fuel and Gado the vehicles, and they attracted additional actors to provide technical support and evaluation expertise. Once the short-term tax exemption ran out, the network width reduced to the OBL alone. Despite network reduction, the particularly close collaboration between industry, farmers' organizations within OBL, which aimed to develop ethanol production based on agricultural crops, indicates relatively high network alignment and power throughout the whole period.

The *expectations* driving the network's activities were that ethanol production would create a business opportunity for farmers and the alcohol industry by creating a new market for domestic starch crops. In addition, ethanol use in vehicles was expected to work well and to contribute to a reduction in both local (smog and lead) and global (greenhouse gases such as CO_2) emissions. The main *lessons* of the bus trial were that driving on ethanol works and that the minor technical problems discovered can be easily resolved. While different *expectations* were stressed by different actors and the wide support for these expectations reduced with the declining network, the positive lessons strengthened the expectations for ethanol as a working and CO_2 emission-reducing vehicle fuel that could be produced domestically and substitute across the entire Dutch bus fleet.

Although a small and isolated ethanol experiment, due to the limited government support, lessons triggered positive expectations within a limited but strong and aligned network and contributed to a plan for a future ethanol plant for which the government granted a longer term tax exemption. The planned plant would initially produce conventional ethanol and later advanced cellulose ethanol once the technology was sufficiently mature. Hence, the developments in this period set a foundation for continued ethanol niche development.

Biodiesel

Network actors	Biofuel	Expectations	Key experiments	Learning	Socio-technical configurations
Municipality, province, public transport company, boating companies, agricultural organizations	RME, pure use	Business opportunity for farmers, way to meet global and mainly local emission reduction ambitions/ standards for inner city water ways	Short-term trial with buses and one train sustained with temporal municipal and EU funding. Initial boat experiment triggers emerging biodiesel boating niche in the context of harsher environmental standards on water ways.	Pure RME works, but not without financing	Isolated experiment that ran as long as EU support or government tax exemptions were provided

After failed attempts to start biodiesel trials, two separate biodiesel *networks* managed to start two experiments. The municipality of Rotterdam and its public transport company ran a three-year bus and train trial and the province of Friesland and various boating companies initiated boating trials. The network around the bus and train trials was broad, including fuel distributors, vehicle providers and emission evaluators. However, it was dissolved as soon as the project terminated. The boating trials had a slightly broader network including fuel distributors, agrarians, local authorities and boating fleets. While broad networks generally contribute to niche development, the isolated experiments limited network collaboration and thus niche expansion.

Like the ethanol expectations, network actors *expected* biodiesel to create business opportunities for farmers and aid environmental emission reductions. However, unlike the ethanol case, local environmental expectations dominated. In the case of the boating trial, harsher environmental regulations regarding surface water and the close connection with biodiesel fuel importers stimulated expectations for biodiesel use as a relatively simple solution to meet the new regulation without reducing engine capacity. The main *lesson* from the experiments was that biodiesel propulsion worked successfully. However, in the bus and train niche the temporary and limited financing from the EU was not enough to support continued experimentation. The boating experiments in this period also had limited support – a two-year tax exemption – but this allowed for several experiments that increased opportunities for niche creation.

The result from this period was a short-lived bus and train trial and emerging and expanding boating trials, which indicates an emergent biodiesel niche. Both trials indicated relatively positive network accumulation and expectations as long as there was sufficient financing. A general barrier to biodiesel niche development was the isolated nature of the activities, which limited network expansion and lesson sharing.

Advanced biofuels

Network actors	Biofuel	Expectations	Key experiments	Learning	Socio-technical configurations
Universities, scientific institutes (BTG), companies (Biofuels BV) and industry (Shell, Nedalco)	HTU, pyrolysis, cellulose ethanol	Benefit global environment, produce more energy and be more cost efficient than conventional biofuels	HTU experiments successful, resulting in the promise of a pilot cellulose ethanol plant in the future	The development of fuels through pyrolysis process not feasible. However, both HTU and cellulose ethanol technology promising, plan for pilot plants.	Isolated HTU and ethanol R&D projects

Scientists, scientific institutes and industry led the advanced biofuel niche. A combined energy and biodiesel network had initiated experiments with pyrolysis and HTU processes in the energy or transport sector in the 1980s. A cellulose ethanol network emerged in the 1990s separate from the biodiesel and bioenergy network. Despite its narrow networks, the involvement of strong actors, such as industry, is likely to have benefitted the development. However, despite beneficial collaboration between bioenergy and biodiesel actors, there was no sign of collaboration between advanced biofuel actors, which is a hampering factor for niche development.

The expectation that pyrolysis and HTU processes would be potentially renewable and sustainable alternatives to fossil-based electricity, heat and motor fuels, made the process technology particularly flexible and interesting for a wide variety of actors, which in turn stimulated technology development. A common expectation for all advanced biofuels was that they would provide a potentially renewable and sustainable alternative for the transport sector. Actors stressed the CO_2 reduction potential in particular. Moreover, network actors expected advanced biofuels to offer more energy- and cost-efficient solutions compared to conventional biofuels, which made them potentially attractive business opportunities for industry. In fact, ethanol actors expected cellulose ethanol production within a 10-year timeframe and biodiesel actors expected HTU to become competitive with fossil-fuel diesel by 2020.

The experiments delivered technical *lessons* that led to the development of a pyrolysis bench-scale reactor, but also to the realization that it was not suitable as a vehicle fuel. This failure to meet expectations led to the termination of the pyrolysis biofuel project. However, in the case of HTU and cellulose ethanol, the positive outcomes of evaluations reinforced expectations and contributed to expanding network support and funds for new projects.

Overall, this period shows limited development, although a foundation was laid for emerging HTU and cellulose ethanol R&D niches. In 1997, there was financing and a network of actors had begun the construction of an HTU pilot. In addition, large-scale funds were granted for a combined conventional and cellulose ethanol plant in which R&D of cellulose ethanol technology could take place.

3.2. AN EMERGENT BIOFUEL DISCOURSE, 1990-1997

Chapter 2 indicates that the oil crisis put alternative fuel and energy development on the Dutch agenda, but a biofuel discourse did not gain ground due to a consensus with regard to the feasibility of energy cropping. However, growing environmental concerns and a crisis in the agricultural sector in the 1980s created opportunities for an emerging biofuel discourse. The latter set the stage for the period 1990-1997, which saw the emergence of a discourse for conventional low technology biofuels alongside an antagonistic discourse on bioenergy.

3.2.1. Conventional biofuels

The government granted its first support measures for biofuels in the early 1990s. It was a tax exemption for small-scale and short-term trials of ethanol and biodiesel. The biofuel discourse that contributed to this development highlighted the potential for biofuels to reduce local and global emissions and the fact that biofuels could aid farmers' financial position by providing an energy crop market in addition to the food crop market.

One of the first to formulate the biofuel discourse was a coalition of the sugar producing farmer cooperations Cosun and CSM, and the alcohol producing company Nedalco, which set up an organization called the Development of Bio-ethanol from Agricultural raw materials (OBL) in the late 1980s. In 1990 they started lobbying for tax exemptions from the government to enable a trial involving ethanol buses in the city of Groningen (Gelderlander, 1996; Van der Veen, 2003). According to Clevering, the former chair of Royal Cooperation Cosun, the parent company of Suiker Unie and Nedalco, the bus trial was a consequence of the responsibility the sugar cooperatives felt for sugar beet farmers in the region (Van der Veen, 2003). According to De Nie (1992), the vice chair of OBL, however, the main motive behind the trial was not to aid farmers, but to aid the environment by reducing CO_2 emissions and smog, and substituting the use of lead as an octane booster with ethanol (De Nie, 1992). In this way, the OBL coalition attempted to gain support using both local and global environmental discourses and a farmer livelihood discourse.

As is noted in chapter 2, local emission reductions of smog and heavy metals was already a policy issue in the 1970s. The idea of global emission reductions is a more recent phenomenon which gained broader attention after the 1987 Brundtland report, *Our Common Future* (Brundtland, 1987). The United Nations Framework Convention on Climate Change in Rio de Janeiro in 1992 put global environmental concerns regarding the need for a reduction in CO_2 emissions on the agenda. It resulted in the first agreement on CO_2 reductions in 1994, and eventually the Kyoto Protocol in 1997. The 1994 agreement was to stabilize CO_2 emissions by 2000 at the level of 1990 (IPCC, 2004).

The increased attention on farmers' livelihoods, however, was a newer phenomenon. It was linked to the crisis in the agricultural sector described in section 3.1, farmers' dependence on EU subsidies while producing surplus food that was dumped on the international market at unreasonably low prices, thereby preventing fair competition by non-EU countries in their own domestic markets. In the Netherlands, the 'Agrification policy' which emerged in the 1980s represented the farmer livelihood discourse. According to Knip (1992) and Van Roekel et al. (2000), the goal of the policy was to increase competitiveness by finding a non-food crop and a related market alongside the conventional food market. This was not a new idea. Non-food production had long been part of the business of the agricultural industry, but the fossil fuel industry took over this role with the introduction of plastics and oil-based chemicals in the 1940s. Alongside the Agrification policy, there was an Agrification movement. In protest at suggested cuts in subsidies for farmers to end surplus production, in the early 1990s farmers drove their tractors to The Hague and set up a demonstration outside the Ministry of Agriculture, Nature and Food Quality. The ministries of Economic Affairs; Housing, Spatial Planning and the Environment; and Agriculture, Nature and Food Qualitydecided to intensify their Agrification activities in response (Knip, 1992; Van Roekel, Koster et.al., 2000).

Meanwhile, at the European Union level, the EU initiated Common Agricultural Policy (CAP) reform. As is explained in chapter 2, this allowed farmers to plant energy crops on set-aside land. In addition, a 1992 EU Directive on Fuels from Agricultural Sources allowed member states to initiate temporary tax exemptions for pilot schemes aimed at the technological development of renewable fuels (Persson & Åsbrink, 1997; Healy, 1994). The core objective of CAP reform was to make the agricultural sector competitive in an increasingly liberalized world. Secondary objectives were to respond to public concern about overproduction, environmental degradation, rural decline and food safety (Koneèný, 2004). Given that the CAP continued to subsidize the agricultural industry, but in a different way, many actors (Koneèný, 2004; Healy, 1994; Daey Ouwens, 1993; Janse, 1996; De Vries, 1996; Volkskrant, 1996) see the agricultural lobby as a main stakeholder in shaping the policy. According to Healy (1994), the growing lobby of European biofuel producers also influenced the reform.

Hence, the fact that EU policy continued to aid farmers but in forms other than production subsidies for food indicates a strong farmer livelihood discourse at the EU level. In the Netherlands, a similar farmer livelihood discourse was reflected in the Agrification movement and related policy. However, general support for biofuel development seems stronger at the EU level, given the early and relatively swift increase in biofuel production shown in Figure 8. In the Netherlands in the 1990s, there was no biofuel production and there were hardly any field trials.

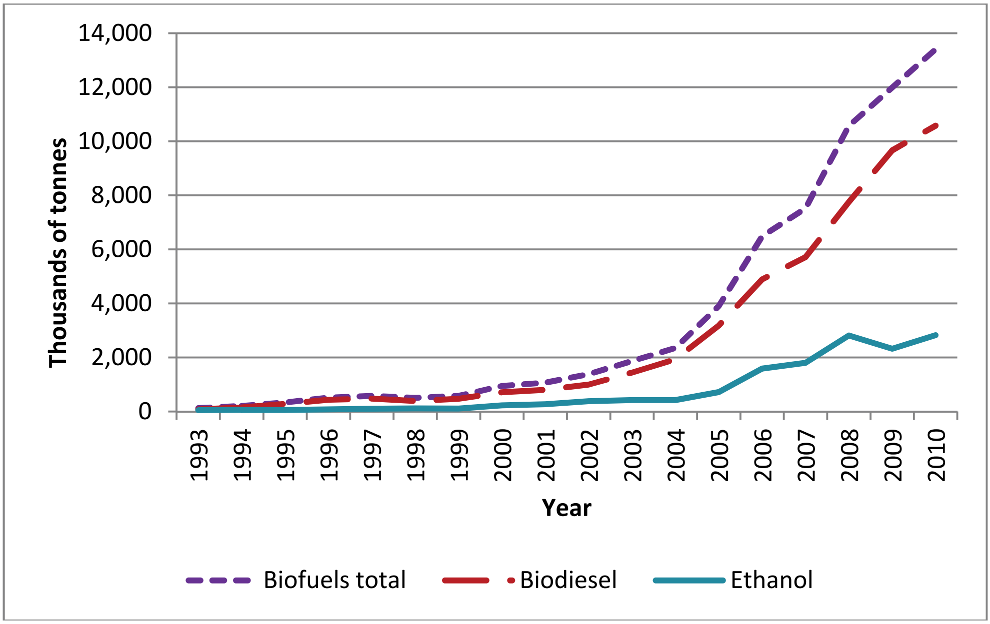

Figure 8: Production of biodiesel and ethanol in the EU, thousands of tonnes, 1993-2010
Source: EurObserv'ER

In the context of the growing farmer livelihood discourse and growing concern over the environment, the ethanol discourse and related coalition activities resulted in limited tax exemptions. According to Wiepkema (1999), the first conventional biofuel trial was an experiment with three ethanol buses in the city of Groningen, which ran from 1992 to 1995.

In parallel with the development of an ethanol coalition, biodiesel advocates started to organize in 1990 (Buddingh, 1991). In 1992, the largest farmers' organization in the Netherlands, Cebeco Handelsraad, mobilized the farmers' organizations in the north of the country in a campaign for a biodiesel tax exemption for oil crops and support to set up a biodiesel processing plant. Like the ethanol coalition, the early biodiesel advocates referred to the potential of biodiesel to improve farmers' livelihoods and the environment, in particular the local environment, by reducing emissions of smog and acids (AD, 1992a). Nonetheless, the campaign did not result in a lasting coalition or government support. In fact, farmers were conspicuously absent from promoting biodiesel in this period. However, the campaign may have stimulated the first biodiesel project, which according to Suurs and Hekkert (2005a), Rotterdam municipality initiated in 1992.

Given the major developments at the EU policy level, the Agrification movement in the Netherlands and the growing environmental concerns, support for biofuels would seem a logical step. However, the biofuel tax exemptions granted for both ethanol and biodiesel were very limited in scope and time. Criticism at the EU and national levels of support for the agricultural sector could explain this.

At the EU level, the European Environment Bureau (EEB) represented the main opposition to continued support to farmers through tax exemptions on biofuels. The EEB is a nongovernmental organization representing the interests of the various environmental organizations in the European Union, and thus also a voice for national environmental interests. [29] According to the EEB, the new EU policy would stimulate farmers to continue environmentally degrading agricultural practices (NRC, 1992b). At the national level in the Netherlands, environmental organizations were not active in this area. Instead, it was the scientific community, which promoted the bioenergy discourse, that opposed EU policy, arguing that conventional biofuels were being supported not because of their sustainable qualities but because the energy crops fitted well with current farming practices (Daey Ouwens, 1993; Janse, 1996; De Vries, 1996; Volkskrant, 1996).

> Nevertheless, these types of conversion routes and application are often neither economically, nor environmentally attractive. It seems like the production of alcohol and biodiesel solely aims to maintain the order of the agricultural infrastructure. (Daey Ouwens, 1993: 10-11, translation by the author)

In this way, the bioenergy coalition used arguments taken from the growing environmental discourse in order to prevent support for conventional biofuels.

Although the emerging biofuel discourse in the Netherlands may not have gained much financial support, there was sufficient support for the government to appoint research groups to evaluate the potential of biofuels. The majority of the evaluations, including the most prominent report by Novem in 1992, were negative towards biofuel development and claimed that biomass for electricity production was a much more promising route from an economic and environmental perspective (Van Onna, 1991; Knip, 1992; Lysen et al., 1992). Even organizations that were expected to defend farmers' interests, such as the National Council for Agricultural Research (NRLO, 1990), did not see any potential for the

[29] Milieudefensie and Stichting Natuur en Milieu are two of the ten Dutch members of this organization (EEB, 2006).

commercialization of biofuels in the next 10-15 years, although unlike other research institutes they were positive about the ecological and economic aspects of biofuels.

The only actor to actively promote biofuel development at this time was the Commission on Agrification, set up by the main advisory body to the government and parliament on social and economic policy – the Socioeconomic Advisory Council (SER). In its 1993 report, the SER argued that the large CO_2 reduction potential of biofuels offset the potentially negative environmental effects and high costs. Hence, the SER recommended that the government: (i) closely monitor biofuel developments abroad; (ii) eliminate regulative barriers to biofuels development; (iii) implement a tax exemption for biofuels; and (iv) facilitate large-scale biofuel trials (EVN, 1993; Spil, 1994).

The response to the SER advice from the Minister of Agriculture Bukman, on behalf of the government was not overly positive. The magazine *Spil* summarized Bukman's letter of response:

> It must be acknowledged that the government response is not reluctant to the SER-advice. It would like to do something – within European boundaries – to look more specifically at biofuels for the transport sector. Nonetheless, it does not recognize the value of 'driving on grains or rapeseed' – especially not for the national agrarian sector or what is left of it. (*Spil*, 1994, translation by the author)

Bukman agreed to monitor technical developments abroad and to eliminate regulative barriers when necessary, but he did not accept the need for a general tax exemption for biofuels or other means to facilitate large-scale biofuel development. Referring to the 1992 Novem report, he argued that the environmental and energy efficiency of biofuels were too low, which made the fuels too expensive. However, with regard to the recent changes in EU policy that had stimulated temporary tax exemptions for biofuel trials, Bukman agreed to support promising small-scale projects in order to gain more insight into the benefits for the local environment and on technological bottlenecks (Spil, 1994). The subsequent energy policy memorandum,[30] published in 1993, was in line with the policy outlined by the Minister of Agriculture and the findings of the Novem report. Government policy presented bioenergy as a promising alternative, compared to biofuel, that was gaining increasing economic support. Moreover, there were low expectations of biofuels as a potential substitute for fossil fuels, since the government saw fossil-based fuel as the main energy source in the transport sector for decades to come. Hence, the only support given to biofuels was in the form of research funds (EVN, 1993; Spil, 1994; Oosterheert, 1993). The political priority for bioenergy dominated the biofuel option throughout this period and the most dominant option was fossil fuels.

That fossil fuel subsidies were granted at both the national and the EU level meant that fossil fuels were likely to remain the main energy source for the foreseeable future. EU data presented by Van Wijnand (1999) show that the EU and its member states gave nine times more energy subsidy to fossil fuel technology than to its sustainable alternatives in 1997 (equivalent to € 9.3 billion for fossil fuels and € 1.35 billion for sustainable fuels). In comparison with the EU, the Netherlands was not that bad. Of the average EU direct energy subsidy, 39% was invested in fossil fuels and 10% in renewable fuels, while the Netherlands invested only 7% of its direct energy subsidies in fossil fuels and 19% in renewable fuels (Van Wijnand, 1999). According a review by the European Environmental Agency (EEA, 2004), Dutch fossil fuel subsidies in the mid-1990s were primarily tax exemptions for less profitable

[30] This memorandum is known as the 'Vervolgnota Energiebesparing' in Dutch.

Dutch gas fields. Furthermore, one should not forget that the fossil fuel sector profits from previous investment in infrastructure.

Despite these negative reactions from the government, the biofuel coalition did not give up. The reaction of the biodiesel proponents was to publish a new report in 1994 by the Amsterdam Institute for Environment and Systems Analysis (IMSA) commissioned by the Western Land and Horticulture Organization (WLTO). The report found that biodiesel produced more environmental gains than earlier anticipated and listed both local and global environmental benefits. Moreover, it was argued that rapeseed cultivation on fallow land, equal to 30 000 ha in the Netherlands, could feed the entire Dutch public transport system (Van Miltenburg, 1995; Van Rhijn, 1995). This was quite a radical statement in comparison with estimates made in the 1970s, when the conclusion was that there was not sufficient cultivated area for energy crops. This is another sign that the biofuel discourse had become embedded in the farmer livelihood discourse.

In parallel with the publication of the report, the government implemented increasingly stringent regulations on surface water quality. Boating companies saw the potential of substituting conventional diesel with biodiesel, which is biodegradable and would help to meet the new surface water standards. New biofuel actors from the Province of Friesland entered the scene to help local boating companies gain tax exemptions for a biodiesel trial. Together they managed to get the Agricultural board of Friesland and representatives from parliament to support their lobbying activity. Two members of parliament, Huys and Liemburg, representing the Labour Party (PvdA), argued that biodiesel was a good solution to water pollution, and the politicians from the Province together with the Agricultural board of Friesland emphasized the future potential for farmers to exploit a new market for rapeseed (FD, 1995; Trouw, 1995). Hence, like the IMSA report, the local biodiesel lobby attempted to embed biodiesel in the farmer livelihood discourse. In contrast to the IMSA, which referred to both local and global environmental benefits from biodiesel, the local biodiesel lobby emphasized only local environmental gains. Biodiesel proponents generally stressed local environmental gains more compared to the proponents of ethanol, who promoted both local and global environmental benefits.

In 1995, Van Miltenburg (1995) reports that the boating trial was granted a two-year tax exemption for the use of 90 000 litres of biodiesel. Final agreement on the trial was probably linked to the wide lobby behind it, which included members of parliament and local politicians, as well as the potential environmental contribution, which was the criteria for funding cited by the Dutch government in its policy brief.

Compared to the biodiesel proponents, the ethanol coalition was more reactive to developments in the policy debate. It was particularly critical of the limited funding that the short-term experiments implied and the negative research results in Novem's 1992 report. A quote from the vice chair of OBL expresses this criticism:

> The researchers from Novem have made mistakes. First of all, they have set too high a price for sugar beet: 111 guilders instead of 70–80 guilders per tonne. The difference is 15 cents on a litre of bio-ethanol. An additional 15 cents may be subtracted from the cost price because the report does not include the profit from by-products, such as pulp. In addition the estimate of the sugar beet harvest is 10 percent too low. This divergence will increase by 2 percent due to environmentally friendly cultivation practices. (AD, 1992c: 5, translation by the author)

In this quote, De Nie argues that several miscalculations were made by the researchers who carried out the Novem study, e.g. that the estimate of the sugar beet price was too high and that by-products were not included. In another article (AD, 1992d), de Nie refers to contemporary discussions in the European Parliament on initiating a general tax exemption for biofuels, which would imply a cheaper price for ethanol compared to fossil fuels. Novem, however, rejected the accusation of miscalculations and defended the accuracy of the data, as did the Agricultural Economics Research Institute (Landbouw Economisch Instituut, LEI) which supplied the data (ibid.).

Even then, the OBL lobby was referring to discussions at the EU level on the implementation of a general tax exemption for biofuels, which according to De Nie would mean that the market price for ethanol would become cheaper than that of its fossil fuel equivalent (AD, 1992d; Paumen, 1994; see also Healy, 1994). In line with the policy changes initiated by the EU, OBL started to lobby at the Ministry of Finance in 1995 for a temporary tax exemption for the production of conventional wheat ethanol and the development of more advanced cellulose ethanol production techniques (Zoethout, 1997; Pols, 1996). Once again the coalition sought to embed the environmental and farmers' livelihood discourses in order to gain a tax exemption. This was reflected in a statement by the director of Nedalco, A. Derde (see Pols, 1996, translation by the author), who argued for financial support by stating that biofuels 'contribute to a better environment, because renewable feedstocks are used in production' and that 'it would also contribute to new work opportunities, not only among suppliers but also among fuel producers'. To put weight behind his argument for financial support, Derde stressed that the Netherlands was lagging behind Europe in developing a biofuel market and the innovation needed to reduce production costs:

> The Netherlands is absolutely lagging behind. [. . .] We want to change this because soon the lag will be so large that we will miss out [on this opportunity]. The 'agrarian nation' France is currently producing more than a hectolitre of bio-ethanol per year. (Derde cited in Pols, 1996, translation by the author)

Even though the Ministry of Agriculture, Nature and Food Quality and Economic Affairs, which was directly involved in the decision-making processes of the Ministry of Finance, seemed reluctant to support Nedalco's plans, members of parliament were positive. In a debate on future energy policy (the Derde Energie Nota) in April 1996, a majority of the lower chamber voted for a re-examination of ethanol's potential and the extent to which financial subsidies could assist ethanol production (Pols, 1996). This new situation and conflicting arguments with regard to the costs of ethanol production led the Ministry of Finance to commission a new study from Novem (Van den Heuvel & Kwant, 1996; Tweede Kamer, 1996). The study, carried out by Bieuwinga and Van der Bijl at the Centre for Agriculture and Environment (CLM), was published in 1996. Like the 1992 Novem report, it stated that biomass for electricity production was preferable to biofuel production. However, the 1996 study was slightly more positive about ethanol: the energy content was estimated to be higher and CO_2 emissions and costs lower (Van den Heuvel & Kwant, 1996). Meanwhile, the global environmental discourse was gaining increased attention, the Kyoto protocol was agreed in 1997 and the government decided to implement a CO_2 reduction plan the same year. This plan reserved 112 million gulden for individual projects related to traffic and transport, hydrogen and biofuels (EVN, 1998). Using funds from the CO_2 reduction plan, the Minister of Finance finally agreed to support the first long-term tax exemption for ethanol in 1997 (Van Miltenburg, 1997). The funding for ethanol in the CO_2 reduction plan demonstrates that the biofuel discourse had become increasingly embedded in the environmental discourse and reached a certain degree of acceptance. This embedding is likely to have contributed to the final decision to support the ethanol trial. However, according to Didde (Didde, 1997) and Stegenga (Stegenga, 1999), the tax exemption still needed the consent of the EU, which delayed its implementation by one year (Didde, 1997; Stegenga, 1999).

The growing attention on CO_2 reduction could also explain the declining attention paid to the farmer livelihood discourse in the mid-1990s. The increasing CO_2 focus meant that many Agrification products could no longer meet environmental standards, which contributed to the termination of the Agrification programme. The development of non-food crops was still supported, however, but under a new name: 'Renewable raw materials' (Van Roekel et al., 2000). For both biomass to electricity and biofuel projects this meant funding from the CO_2 reduction plan (Van Roekel et al., 2000; EVN, 1997b). This did not mean that the farmers' livelihood discourse disappeared, but the way in which biofuel coalition actors referred to the discourse became more subtle for strategic reasons. I return to this point below.

The increasingly dominant role of the global environmental discourse can also explain the increased attention paid to advanced biofuel applications in the bioenergy discourse. In turn, the growing attention on CO_2 emissions and advanced biofuels is likely to have contributed to interest in the development of cellulose ethanol by conventional ethanol actors (Nedalco) and to the fact that the government agreed to give large scale and long-term funding to the project in question.

3.2.2. Bioenergy and advanced biofuels

In the early 1990s, bioenergy advocates were trying to gain increased recognition for the bioenergy discourse by linking it with the global environment discourse. In the many reports (Van Onna, 1991; Van den Heuvel & Kwant, 1996) and other academic work (Van Onna, 1991) published in the early 1990s (Lysen et al., 1992; Biewinga & Van der Bijl, 1996; Daey Ouwens, 1993; Van Doorn, 1993), one strategy to gain recognition for bioenergy was to present the conversion of wood to energy as much more energy and environmentally efficient than the conversion of agricultural crops to biofuels.

A new and highly technical route for the production of biofuels for the transport sector emerged in parallel with the debate over producing biofuel from crops or wood biomass for energy production. There were three central conversion routes for using woody or waste biomass: first, a fermentation route to produce cellulose ethanol; second, a thermal process for developing a Pyrolysis oil; and, third, a Hydro Thermal Upgrading (HTU) process that converts wet biomass to liquid oil (Daey Ouwens, 1993; Okken, 1989; EET, 2001). Many of these techniques were researched and experimented with in the 1970s and 1980s as a means for dealing with the increasing problem of waste disposal in the Netherlands and elsewhere (Van Zijl, 1981; Van Rutten, 1987; Van der Knijff, Wildschut, & Williams, 1991). This means that they were initially part of the bioenergy discourse. According to a report by the EET programme (EET, 2001), only the HTU process, developed by Shell in the 1980s, was developed with the primary intention of producing a fuel for the transport sector.

Funds had been difficult to mobilize for conventional crop-based biofuels, and the fact that the 1993 energy policy memorandum stated that biofuel R&D projects would gain funds is likely to have made it easier for advanced biofuel options to gain support. The number of years that the four research programmes supported R&D projects compared to the short time that the four field projects were running (see Table 3) provides evidence for this assertion. Although documentation on funding is absent in most cases, it is possible to conclude that the actual financing necessary for R&D projects was generally lower than the tax exemptions. Hence, financial reasons could well add to the explanation why the government was willing to fund many R&D projects but only a limited number of tax exemptions.

According to Raven and Verbong (2001), the funding given to the research on biofuels was very limited. Biofuel R&D funds came from the EWAB and other energy R&D programmes. In fact, the proponents of advanced biofuel had much in common with bioenergy proponents. A number of publications (Daey Ouwens, 1993; Janse, 1996; De Vries, 1996; Volkskrant, 1996) indicate that researchers on new biofuels and bioenergy shared the opinion that conventional biofuels were not of sufficient quality. They argued that conventional biofuels were supported not because of their sustainable qualities, but because these crops fitted well with current agricultural practices (ibid.; Volkskrant, 1996). Moreover, the strategy applied to the emerging advanced biofuel discourse, based on pyrolysis and HTU technologies, was to present the technology as promising for both the energy sector and the transport fuel sector (BTG, 2006; DE, 1996; EVN, 1996; Okken, 1989; DE, 1996; EVN, 1996). Hence, the assumption seems valid that much of the funding gained for the advanced bio-oil and biodiesel options was thanks to the growing bioenergy discourse.

In fact, there is evidence of an advanced biofuel discourse emerging within the bioenergy discourse. One of the first to articulate this discourse was Daey Ouwens, who was a central figure in this coalition. According to Daey Owens (1993), novel biofuels and bioenergy based on energy crops such as straw and wood as well as waste materials have many advantages. First, they are a reliable and cheap energy source. Second, the damage they do to the environment is marginal compared to conventional biodiesel. Third, they contribute to a better use of agricultural land. Fourth, they increase the number of jobs in areas where unemployment is high. Fifth, they cut dependence on oil exporting countries. Despite common references to the environmental discourse in the field of bioenergy, it is interesting to note that Daey Owens referred to the farmers' livelihood discourse. In midst of a bioenergy discourse opposing support for conventional farming practices, however, these references were more subtle – referring to the general issue of reducing unemployment in the countryside. Moreover, this was one of the few occasions on which the advanced biofuel coalition made direct reference to the oil substitution discourse, a discourse that had not been heard about since the early 1980s.

Despite these new developments, the new and technically advanced biofuels did not get much attention in politics or the media during this period. The central issue in the Dutch debate at that time was the relative merits of using wood and waste biomass for energy production versus the cultivation of oil, sugar and starch crops for biofuel production.

3.2.3. Discourse analysis, 1990-1997

Policy	Level	Year	Type	Size	Description
General					
CAP reform	EU	1992	Regulation		10% of agrarian land set aside. Compensation given for financial loss and energy crops still allowed.
Directive on Fuels from Agricultural Sources	EU	1992	Regulation		Temporary tax exemptions allowed pilots on the development of renewable fuels.
Rio de Janeiro declaration	UN	1994	Agreement		Non-binding agreement to stabilize CO_2 emissions in 2000 to the level of 1990.
Kyoto Protocol	UN	1997	Agreement		Non-binding agreement on CO_2 reduction by 2012 with 1990 as reference value.
'Energy for the Future…'	EU	1997	White paper		One means to reach agreement on CO_2 reductions is to reduce the production costs of biofuels, and provide general tax exemptions and additional subsidies for energy crops.
Bioenergy/ advanced biofuels					
Agrification programme	Government	1985-1995	R&D, reports	S	Focus on non-food products, limited recognition of biofuels
EWAB R&D programme	Government	1989-	R&D, reports	S	Focus on bioenergy, biofuel sidetrack only
Renewable raw materials programme	Government	1995-	R&D, reports	S	Focus on non-food and the environment, biofuels is one among many products explored.
EET	Government	1996-	R&D	S	Economy, ecology and technology R&D programme, limited funds for bioenergy and biofuels
Conventional ethanol					
Buses Gado	Government	1992-1995	tax exemption	S	3 years for 3 buses
Plant Nedalco	Government	1997-	tax exemption & R&D	M	10-year exemptions & subsidies for conventional ETBE plant, future cellulose ethanol plant and R&D.
Conventional biodiesel					
Buses RET 1	Municipality	1992-1993	tax exemption	S	1 year for 3 buses and 1 train in Rotterdam
Buses RET 2	EU	1994-1995	tax exemption	S	1 year for 9 buses in Rotterdam
Boats H&R	Government	1995-1997	tax exemption	S	2 years for 70-108 boats

Table 3: Biofuel-related policy support, 1990-1997

Conventional biofuels

Ethanol

Biofuel	Discourse	Mobilization/ impact of wider discourses, events and policies	Discourse coalition	Target audience	Key activities, strategies	Resulting space/ policy creation or disruption
Ethanol pure use and production	Ethanol as a means to reduce global and local emissions and aid economy of farmers and producers; also reference to cellulose ethanol as a future solution once mature. Swift develop-ment argued to avoid lagging behind EU states.	Embedding sought in farmer livelihood discourse triggered by EU CAP reform and the environ-mental discourse which took on a more CO_2 oriented character in the 1990s.	Farmers, industries (Suikeruni, Nedalco)	Government and consent from the EU to give tax exemption for plant	Lobbying for financial support and longer tax exemptions. Particularly to set up production plant, which were to bridge conventional with cellulose ethanol. In addition, they seek media attention, take space in policy debate and react to 'negative' scientific findings.	Short-term tax exemption for bus trial and long-term tax exemption for production of future conventional and cellulose ethanol plant.

Biodiesel

Biofuel	Discourse	Mobilization/ impact of wider discourses, events and policies	Discourse coalition	Target audience	Key activities, strategies	Resulting space or policy creation / disruption
Biodiesel production and pure use	Biodiesel as a means to produce mainly local but also global environmental benefits, its potential to substitute in the entire Dutch diesel fleet and aid farmers' livelihoods and regional development in general.	Embedding sought in farmers' livelihoods discourse triggered by EU CAP reform as well as the environ-mental discourse.	Farmers' organization, Province of Friesland, Politicians. Certain circulation of actors in the early 1990s compared to the end of the period.	Govern-ment	Lobbying for financial support to set up production plant and tax exemptions for field trials.	Short-term tax exemption for biodiesel in boats.

A crisis in the agricultural sector at the EU and national levels facilitated the emergence of the biofuel discourse. This emerging discourse was embedded in a general farmers' livelihood discourse by portraying ethanol and biodiesel as means to boost farmers' livelihoods. However, at the end of the period, a more general regional development argument substituted for the farmers' livelihood argument. A more central feature of the discourse was the potential for biofuel to reduce emissions. Initially, the discourse stressed the local emission reduction potential of biofuels, while the potential for global CO_2 emission reductions dominated at a later stage. This indicates embedding in an environmental discourse, which evolved into an increased focus on CO_2 emission reductions. In a quote by the CEO of Nedalco, the potential for biofuels to aid both farmers' livelihoods and the environment is visible. He argued that biofuels would 'contribute to a better environment, because renewable feedstock is used in production' and to 'new work opportunities, not only among suppliers but also among fuel producers'. At the end of the 1990s, proponents of ethanol used these arguments to promote advanced biofuels as well. One argument to gain support for both conventional and advanced biofuel development was reference to the Netherlands as 'lagging behind' Europe and 'missing out' on market opportunities.

There were two biofuel coalitions behind the biofuel discourse. First, there was an ethanol coalition of farmers' organizations and the alcohol industry organized into an ethanol development network – OBL. Second, there was a weak biodiesel coalition represented by farmers and municipalities. The inclusion of production- and user-oriented coalition actors and powerful actors such as industry and farmers (backed up by the Agrification movement) was promising for niche development. The various lobbying strategies used involved campaigns oriented towards the public, but also lobbying at the parliamentary level and through the media using scientific reports to argue against statements that land for rapeseed cultivation was too limited and ethanol too expensive. Decreased references to farmers was a strategic way to avoid increasing criticism of biofuel as only a means to maintain the agricultural infrastructure order. The decision by the ethanol lobby to support the idea of ethanol production from waste crops to cellulose waste feedstock in the future is probably also a strategy to stress environmental gains and avoid the negative association of biofuels as just a farmer subsidy. The continuity and alignment of lobbying activities were particularly visible in the ethanol OBL network.

Throughout this period, government support for biofuels had been generally short term and ad hoc. The growing biofuel coalition, and the positive properties of the ethanol coalition in particular and its strategic activities, resulted in the granting of a longer term tax exemption for a combined conventional and advanced ethanol plant at the end of the period. A competing discourse, the bioenergy discourse which emerged in the previous period, can partly explain the resistance to supporting biofuel. The supportive scientific arguments presented by the bioenergy discourse led the government to refrain from giving more support to biofuels.

Advanced biofuels and bioenergy

Biofuel	Discourse	Mobilization/ impact of wider discourses, events and policies	Discourse coalition	Target audience	Key activities, strategies	Resulting space/ policy creation or disruption
Bioenergy and advanced biofuels	Bioenergy was generally seen as a better alternative than biofuels but if CO_2 emissions were to be reduced in the transport sector, advanced biofuels from waste and cellulose feedstock was the only option. They were also seen as contributing reduced oil dependency and job opportunities in provincial areas.	Embedding was sought initially in the global environmental discourse and later in the regional development discourse.	Initially, waste managers, the energy industry and scientists. Post-1995, increased focus on scientists. Nedalco also supported cellulose ethanol.	Govern-ment reaction to EU policy that, according to the coalition, continued to support farmers.	Lobbying against government support for conventional biofuel. Use of media and scientific publications to disseminate discourse.	Limited but continuous R&D funds (EWAB and various bioenergy R&D pro-grammes).

As in the 1970s, the focus on the bioenergy discourse remained on bioenergy from waste as far more energy efficient, and more economically and environmentally attractive than conventional crop-based biofuels. In the words of one coalition member, Daey Owens, in 1993, conventional biofuels ‘are often neither economically, nor environmentally attractive. It seems like the production of alcohol and biodiesel solely aims to maintain the order of the agricultural infrastructure’. On environmental benefits, the focus was on the potential for CO_2

reductions. Despite the rejection of conventional biofuels, the bioenergy discourse displayed increasing acceptance of biofuels from waste and wood crops over time, which was shown in the increased granting of applications for the development of process technologies that could be applicable to both the energy and the transport fuel sector. Through these means, an advanced biofuel discourse was emerging within the bioenergy discourse at the end of this period. Hence, the discourse on advanced biofuels was similar to that on bioenergy from waste. The additional benefits mentioned for advanced biofuels were increased employment and oil substitution. The CO_2 reduction focus in the bioenergy and advanced biofuel discourses required embedding in the environmental discourse, which had gained a more global focus. In addition, because of the agrarian crisis, the advanced biofuel discourse attempted to embed itself in the farmers' livelihood discourse. The acceptance of energy cropping of wood and grasses during this period marks a clear shift in the bioenergy discourse, which had previously deemed energy cropping for biofuels impossible in the Netherlands.

Initially, both waste managers and the energy industry were part of the bioenergy coalition together with scientists. The increasingly high-tech focus post-1995, driven by the scientific community, however, meant that scientists started to dominate the coalition. This was visible in the coalition's activities, which mainly consisted of producing scientific publications and reports used in media and policy debates to influence government bodies. This reduction in the variety of coalition actors was a weakness, as was the limited support for advanced biofuels at first. However, the increase in advanced biofuel lobbying activities that answered to the changing discourse landscape indicates increased discourse acceptance.

Emerging advanced biofuel proponents within the bioenergy discourse resulted in continuing but limited financial support through bioenergy R&D programmes such as the EWAB and other less well-defined research funds. While advanced biofuels gained more attention than before, the main debate in this period was whether government policy should support bioenergy alone or support both bioenergy and conventional biofuels in order to reduce CO_2 emissions.

3.3. CONCLUSIONS: DUTCH BIOFUEL DEVELOPMENTS, 1990-1997

This section concludes the biofuel developments in the period 1990-1997. I present the conclusions from two perspectives: an SNM perspective and a discourse perspective.

3.3.1. Concluding biofuel niche developments

In the period 1990 to 1997, biofuel actors developed or introduced a small number of biofuel initiatives. I divide these initiatives into two emergent biofuel niches: a conventional technology niche and an advanced R&D niche. The conventional biofuels experiments were small-scale and short term. The advanced biofuel experiments were also small-scale, but stretched over a longer period, indicating increased continuity.

The difference in continuity is surprising given the niche processes of the different biofuel niches. The conventional biofuels had generally positive niche development patterns, such as broader networks and lessons that to a large extent met positive expectations. The advanced biofuels had narrow networks and learning processes, and were far from meeting expectations due to the immaturity of the technology.

The reason behind the different niche development patterns was the difference in government support. Government funds for conventional biofuels were short term and ad hoc, while funding for advanced biofuels has been uninterrupted. The amount awarded may not have differed that much between the conventional and advanced biofuels, because tax exemptions are generally much more expensive than research funds. Moreover, much of the funding for and experimentation on advanced biofuel processes was as a result of bioenergy actors' efforts to further the bioenergy niche.

The limited and ad hoc support given to biofuel implementation indicates the lack of a government biofuel management strategy, which is also the main reason for the lack of biofuel niche development in this period.

3.3.2. Concluding biofuel discourse developments

The period 1990-1997 saw the emergence of two novel discourses: a conventional biofuel and an advanced biofuel discourse. The advanced biofuel coalition emerged from within the bioenergy discourse. Agrarians and local authorities were the main actors in the conventional biofuel coalition. Temporary concerns over farmers' livelihoods at the EU level and growing concerns over CO_2 emissions globally facilitated the development of the biofuel discourse. The Dutch government supported conventional biofuels for environmental reasons, but only by means of small-scale and temporary tax exemptions. One reason for the limited government protection for conventional fuels was a competing bioenergy coalition dominated by scientists. Despite criticism of conventional biofuels by the bioenergy coalition, the growing need for CO_2 reductions in the transport sector led to an increased acceptance of alternative and advanced biofuels within the bioenergy discourse.

4. ADVANCED BIOFUEL TAKES CENTRE STAGE, 1998-2002

This chapter examines biofuel developments in the period 1998-2002. First, I describe the development of the biofuel niche and present an SNM analysis. I then discuss the political processes leading up to biofuel-related policy measures, and present a discourse analysis.

4.1. TOWARDS AN INITIAL BIOFUEL MARKET, 1998-2002

4.1.1. General policy developments

In the period 1998-2002, the government initiated the GAVE programme, the first programme especially tailored for biofuel and bioenergy development and implementation. At the same time, however, the government ended the limited tax exemptions for conventional biofuel experiments that emerged in the previous period.

4.1.2. Conventional biofuels

Ethanol

In the first period examined in this study, Nedalco gained large funds and a long-term tax exemption to commercialize the production of conventional ethanol and ETBE and develop novel production technology based on cellulose ethanol. Once Nedalco had obtained funding approval from the government and the EU in 1998, however, news on the ethanol project ceased: the test plant Nedalco wanted in order to achieve commercial ethanol production was never built. According to the biofuel project manager at Nedalco (personal communication, 18.10.2005), the project failed because Nedalco's project partners, Lyondell and Shell, withdrew. The partners considered the investment capital and the production quota too small to be of commercial interest. Hence, Nedalco did not take up the funds granted by the government (ibid.). The project failed despite the fact that the biofuel subsidies were the most generous and available for the longest duration thus far. There would be no further activity in the field of conventional ethanol development during this period. Nedalco, however, continued to invest time and energy in the development of ligno-cellulose ethanol production techniques.

Biodiesel

Although ethanol was not seen in the biofuel niche during this period, activities continued in the biodiesel field. The Agricultural Board of Friesland reported in 1998 that the two-year trial carried out by Holiday Boatin' and Roukema had been running satisfactorily. The tax exemption was due to end in 1998, so the boating companies asked the Ministry of Finance for a continuation in 1997. However, continued funding was not granted by the Ministry and the trial ended (Evers, 1998). The waterbus trial in Amsterdam carried out by Kooij and Plas had also been running successfully. They had tackled initial problems with odours of deep fried food using catalysts. However, unlike the Holiday Boatin' and Roukema trials, the waterbus trial did not end once the tax exemptions ended in 1998 (Evers, 1998; Klipp, 1998). Part of the explanation for this is that the tax exemption did not provide any financial incentive in the case of Kooij and Plas. According to Pennewaard (2000a), Kooij and Plas was already exempt from fuel tax on fossil fuels and bio-based fuels due to a shipping fuel regulation known as 'bunkervergunning'. Although this regulation applied to the Province of Friesland as well, it did not apply to companies such as Holiday Boatin' and Roukema (Pennewaard, 2000a).

Hence, the main incentive to continue the use of biodiesel by Kooij and Plas remained to meet stringent environmental standards.

Compared to the above two trials, the results of the 18-month trial in the Province of Friesland were less positive. Six of seven ships had continual engine problems, despite the adjustments made to the diesel engines. Only the ship which had had a new motor constructed for biodiesel propulsion only ran without complications. Moreover, there were complaints about the smell (Evers, 1998). According to the technical consultant, Klaver from Rolde, and the fuel importer, Van Gelder from Nijmegen, the problems encountered in Friesland were linked to the fact that the diesel engines were new. Using biodiesel in new diesel engines causes congestion problems leading to incomplete combustion and eventually to more emissions than the combustion of fossil diesel. The biodiesel importer and distributer, Wiersma, contests this argument, arguing that he had never had any problems with diesel engines running on biodiesel (Marx, 1999a). However, he does not mention the age of the engines. The result was increasing doubt about the benefits of continuing the trial at the provincial level. While the Province had a tax exemption for mineral oil that was similar to that of Kooij and Plas, critics there argued that the annual cost of the project, € 45.000, was too high. The farmers' organization, Northern agricultural organization (Noordelijke Land-en Tuinbouw Organisatie, NLTO), and Wiersma backed the supporters of the trial (Hettema, 1999). They recognized that only a biodiesel tax exemption would attract additional actors, such as local farmers, fuel producers and fleet owners, to the project. Consequently, the biodiesel actors asked for a tax exemption from the Ministry of Agriculture, Nature and Food Quality (Volkskrant, 1999), but the government initially rejected the request. Eventually, however, after repeated requests, the government gave the biodiesel actors a new tax exemption, valid from 2002 to 2005 (Vanlierop, 2001). Seven boats from the Province of Friesland and the boats owned by the local boat rental companies Holiday Boatin' and Roukema made use of this tax exemption. The NLTO participated in the project. Its main task was to investigate the possibility of cultivating rapeseed in the Netherlands for the boating experiments. The Province put an extra € 152 000 into the maintenance budget for the boats in order to deal with the deep fried odours (DE, 2002b). However, it was not only the biodiesel actors that gained a tax exemption, the PVO actors gained one too.

PVO

Pure Vegetable Oil (PVO) entered the stage at the turn of the century, led by two entrepreneurs – the father and son Hein and Ron Aberson. The Abersons' initial interest in PVO emerged from Ron Aberson's experience with PVO and close cooperation with Professor Elsbett while working in Germany as an engineer. Their primary aim was to safeguard the environment, and their secondary aim to end dependence on fossil fuels and become self-sufficient by means of PVO. Their first act was to bring Elsbett engine technology to the Netherlands and experiment with it by rebuilding vehicles to run on PVO. In addition to fuel, they recognized the broad applications of PVO, as a raw material for food, as animal feed and for producing heat and electricity. The ambition to become self-sufficient with regard to fuel led to the setting up of an oil mill, pressing rapeseed for its oil. Together with the engineering bureau, IHN, the Abersons wrote a business plan for the oil mill which estimated the costs at € 1.5–2 million at an annual production of 3 million litres of oil. The estimated price of oil from the mill was € 0.57 per litre, which was cheaper than the price of diesel (€ 0,80) at the time. The main partner for the Abersons was the NLTO, but some 25 additional partners were also part of the network in the early phase of the project. The majority of the network actors were farmers, but the Northern Development Cooperation (NOM) and the Municipality of Venlo in the south of the country also participated (Bijlsma, 2002b). To realize their plans the Abersons asked for a tax exemption from the Ministry of Finance. Despite several rejections, they did not give up (Solar Oil Systems, personal communication, 18.06.2007). The tax exemption eventually granted covered the use of PVO in 350 vehicles, or 3.5 million litres of PVO annually, in the period 2002–2010 (Bijlsma, 2002b; Bijlsma, 2002c). The Abersons started the company Solar Oil Systems the same year the tax exemptions were announced (Bosker, 2002).

The success of PVO production and marketing in Germany inspired the Abersons to follow a German model, in which the farmers not only grew the rapeseed, but also became stockholders in the oil mill producing the rapeseed oil. Together with Hamster from NLTO, the Abersons tried to mobilize farmers to participate in the project. The farmers were reluctant, however, and starting the project turned out to be more difficult than anticipated. In particular, the subsidy for non-food cultivation from the European Commission was problematic. These subsidies were only granted if the farmer in question paid a deposit, which was 50% of the eventual subsidy received once the product reached the market (Bijlsma, 2002a; Bijlsma, 2003g). Attempts to gain funding from the government had no success. By late 2002, investment levels were still uncertain and there was no clarity with regard to the future of the oil mill. The Abersons maintained their confidence in the mill project, however, as increasingly positive experiences from Germany and from new field experiments in the Netherlands led to increased media attention on PVO (Bijlsma, 2002c).

These field experiments were the Abersons' experiments with their own PVO vehicles and a trial involving a street cleaning vehicle in the municipality of Venlo, in which the Abersons assisted with technical know-how (Bijlsma, 2002c; FD, 2003). The latter was initiated in September 2002 (GAVE, 2003d). Venlo became the first municipality in the Netherlands to run part of its fleet on PVO. The municipality considered PVO both environmentally friendly and cheap. The municipality aimed to save € 0.20 on each litre of fuel used, which was a lot of money given that it was using 80 000 litres of fuel per year (Stromen, 2002b). At this point, PVO fuel delivery was not an issue since the amount of PVO being used was limited. In fact, the Abersons used vegetable oil from their store (Bijlsma, 2002b).

4.1.3. Advanced biofuels

Ethanol

During this period, the GAVE subsidy programme created increased opportunities for the development of advanced biofuels. The programme was managed by the government agency Novem and financed by the Ministry of Economic Affairs. The GAVE programme aimed to stimulate and speed up the introduction to the market of advanced liquid and gaseous biofuels and bioenergy technologies. It began in 1999 as a means to meet national CO_2 emission reduction targets (Van den Heuvel, De Zeeuw, & Stuij, 2000). In order to determine which fuels would qualify for funding from the GAVE programme, an evaluation of the different fuel options was carried out by an external consultancy firm. Cellulose ethanol was considered the most promising alternative to and substitute for fossil fuels, especially gasoline (Little, 1999). Despite these high expectations for ethanol, advanced bio oil and biodiesel actors were the only ones to apply for funding from the GAVE programme. That Nedalco had failed to build a combined conventional and advanced ethanol plant despite government funding in 1997 could explain this lack of interest in ethanol in the GAVE programme.[31] This may relate to the disappointment that followed this failure, or increased experience regarding the components needed – in terms of funds and actors – to achieve market implementation.

---

[31] See the secton on conventional ethanol above for more information on the failure to build the plant.

There were other sources of funding for cellulose ethanol R&D during this period. These funds were motivated not only by its expected ability to reduce CO_2 emissions, but also by the availability of new biomass waste streams. According to Vis (2006), new R&D funds emerged due to the occurrence of various animal diseases in Europe at the turn of the century. As a result, new regulations prohibited the use of many animal-based by-products in animal feed. The risk of Bovine Spongiform Encephalopathy (BSE) among animals, which can cause Creutzfeld-Jakob disease in humans, meant that prohibitions were particularly strict on using animal fat and proteins as feed (Vis, 2006). These new regulations created new opportunities to use animal-based by-products for non-food applications, such as biofuels (Elbersen, Kappen, & Hiddink, 2002).

The Ministry of Economic Affairs supported a proposal to research the potential for biomass and biofuel production from these by-products. Nedalco, ECN, ATO at University of Wageningen, the University of Delft and Shell Global Solutions obtained a grant in 2000 from Novem's Economy, Ecology and Technology (EET KIEM) R&D programme for research on cellulose ethanol, electricity and heat production from biomass residues. The results, presented in 2002, indicated that this type of ethanol production could become competitive with gasoline only in the long term. As a result, a relatively new actor in this field applied for a four-year follow-up research grant from the EET programme in 2002 (GAVE, 2002a; Reith & de Bont, 2007). Meanwhile, Nedalco started to cooperate with TNO on cellulose ethanol. They obtained funds from the EET programme and started a project, 'ThermoZym, cellulose conversion for the production of ethanol'. Two TNO institutes, the TNO Environment, Energy and Process Innovation (TNO MEP) and TNO Foods, collaborated with Nedalco on this project, which ran from October 2001 to November 2002 (SenterNovem, 2005e). At the same time, TNO MEP and Nedalco took on a second project with funds from the EET programme from February 2002–September 2003. This project was 'A radically new approach to the production of bio-ethanol'. It investigated the potential for the production of bio-ethylene, a gaseous fuel that the project actors aimed to produce from ethanol (SenterNovem, 2005f).

Biodiesel and bio oils

The start of the GAVE programme offered great opportunities for biodiesel and bio-oil options. According to Van den Heuvel et al. (2000), a budget of € 18.1 million had been reserved for the planned GAVE programme in 1997, of which a large part would be spent on advanced biofuels that met its high expectations for CO_2 reductions.

One of the new fuels supported by the GAVE programme was Fischer-Tropsch diesel (FT diesel). This fuel is an old coal-based technology, which Germany applied on a large scale during the Second World War to substitute for scarce oil-based diesel (ECN, 2007). Petrochemical companies like Shell in Malaysia and Sasoil in South Africa still use coal or Compressed Natural Gas (CNG) as a feedstock for FT diesel production (ECN, 2008a). To reduce CO_2 emissions, various researchers started to investigate the possibility of producing FT diesel from bio-based gas, that is, Synthetic Natural Gas (SNG). Within the GAVE programme, A.D. Little (1999) was one of the first in the Netherlands to highlight FT diesel as the most promising substitute for fossil diesel. It was considered not only to have great CO_2 reduction potential and low costs, but also to fit very well into conventional technologies for diesel storage, distribution infrastructure and engines. Subsequently, two projects were funded for a feasibility study in the first round of GAVE projects tendered in 2001. The funding was around € 113 000 per project (Tweede Kamer, 2002). The first project, Biomass Integrated Gasification FIscher-Tropsch (BIG-FIT), originated from a consortium set up by ECN, the renewable energy research and consultancy firm, Ecofys, Shell, Rabobank and Volkswagen in

1999. The Agency for Research into Sustainable Energy (SDE) received the funds and acted as coordinator. The project's aim was to investigate the feasibility of the co-production of FT-diesel, electricity and heat in an integrated installation involving a gasifier, a Fischer-Tropsch synthesizer and a heat and electricity generator. While none of the actors above possessed the hardware, they had knowledge of the process technologies involved in the production chain. The ECN consortium saw Rotterdam Harbour as the ideal location for a large-scale plant. The harbour became involved in the acquisition and other logistics related to the front and end of the production chain (SDE, 2002). Based on 20% implementation in the fuel market, the SDE expected a CO_2 emission reduction of 2.7 million tonnes per year (Bosch, 2002). The second consortium to receive finance from the GAVE programme was managed by TNO-MEP in cooperation with Sasol Technology, the energy company, Nuon International, and Demkolec, which manages an integrated coal gasification combined cycle (ICGCC) power plant in the Netherlands. Unlike the BIG-FIT SDE project, which focused on the development of various products, the aim for the TNO-MEP project was the development of FT diesel alone. The production process included gasification of biomass, potentially the co-gasification of biomass with coal, and a synthesis of the gas to produce FT-diesel. The project partners expected a first demonstration of FT diesel by 2004–2005. Based on estimates of a 10 % FT diesel implementation, an annual CO_2 reduction of 1.5 million tonnes was expected (Bosch, 2002). Unsurprisingly, both groups concluded that FT technology had great potential, not the least when it came to CO_2 reductions and cost-efficiency. Despite this conclusion, no follow-up demonstrations were initiated (GAVE, 2002d). According to SDE, there were too many technical barriers, which prevented large-scale demonstration projects. The main barrier was the need to clean the synthetic gas, which according to SDE would require some years of fundamental research (GAVE, 2002d; SDE, 2002). In the case of the TNO alliance, one barrier to continued FT-diesel development was that the partners no longer shared the same goal. A report published by TNO (Jansen & Berends, 2002) indicates that TNO still believed in FT-technology. It concluded that co-production of FT-diesel and electricity from the gasification of biomass and coal was more feasible than the production of SNG and electricity from the same source (ibid.). Nuon, however, was not of the same opinion and chose to continue with SNG and electricity production alone. The reason for Nuon's choice was threefold. First, the production of FT-diesel did not fit the Nuon energy company profile. Second, Nuon expected that the SNG production process would produce more CO_2, which it could sell to the greenhouse sector. Third, new tax exemptions on sustainable electricity under the tax scheme regulerende energiebelasting (REB) meant that Nuon saw greater certainty in gaining tax exemptions for SNG than for FT-diesel (Jansen & Berends, 2002).

Despite the termination of FT diesel research within the GAVE programme, an alliance of Biomass Technology Group (BTG) and Shell Global Solutions managed to gain three years of funding through the Novem EET programme in 2001 for a project on 'Sustainable gasoline and diesel from biomass via pyrolysis and Fischer-Tropsch process'. This was a combination of pyrolysis and FT-technology, where bio-oil produced from the pyrolysis process was the expected feedstock for FT-diesel (SenterNovem, 2005b). The results of this project are presented in Chapter 5.

HTU was not new to the Dutch researchers, but it was nonetheless considered a promising alternative in the 1999 GAVE evaluation (Little, 1999). The NLG 11 million received from the EET programme in the period 1997 to 2001 resulted in the setting up of a test installation in Apeldoorn in 1999 (Marx, 1999b; SenterNovem, 2005d). This test installation could deal with 10–20 kg of biomass per hour. The process delivered 50% biocrude and 50% water as well as various other waste-products. Naber, one of the engineers who promoted HTU in the company Biofuel B.V., argued that the HTU process was particularly energy efficient, since the production process was fuelled by only 15% of the total biomass input. With regard to CO_2 efficiency, Naber argued that saving one tonne of CO_2 cost € 36, which was cheaper than CO_2 reduction by means of wind and solar power. Nevertheless, the costs of producing HTU oil were high in comparison with fossil oil (Marx, 1999b). In September 2002, Naber gained a further opportunity to develop the HTU project by means of a subsidy from the GAVE programme of approximately € 100 000 (EVN, 2002; Knoppers, 2002). In this project, Biofuel B.V. continued to work with Shell Research, but the other partners were new. The additional actors were the Municipal Waste Processing Agency of Amsterdam (Gemeentelijke Dienst Afvalverwerking, GDA),[32] TNO Automotive and Van de Sluis Handelsmaatschappij (Knoppers, 2002). From 2002 to 2004, new research activities were undertaken with the general aim of facilitating the up-scaling of the pilot plant in Apeldoorn. Examples of the subgoals outlined were to achieve a controlled operation at the pilot plant and to gain a clear perspective with regard to the product (Stromen, 2002a). Biofuel B.V. planned its first demonstration project in 2007. After market introduction, the estimated CO_2 reduction could reach up to 3.35 million tonnes per year on the basis of a diesel oil market penetration of 5.2% (Knoppers, 2002).

In addition to FT diesel, Dimethyl Ether (DME) was a transport fuel alternative that was highlighted in the 1999 GAVE evaluation. Unlike FT diesel, the evaluation did not present DME as one of the most promising options (Little, 1999), but, like FT diesel , DME relied on the gasification of fossil or biomass feedstock as a first step, followed by a conversion process to DME. The technology received new interest due to developments in Denmark in the 1990s. In 1997, the TNO section focusing on road transportation introduced DME experiments in the Netherlands with funding from the International Energy Agency (IEA). According to an announcement by TNO, the price of DME was equal to fossil diesel but there were still technology bottlenecks that prevented market introduction. One was the corrosive nature of the fuel, which meant that most rubbers and plastics could not tolerate DME. Another was the need for a new fuel injection system (EVN, 1997a). In addition, the similarities in the production processes of DME and FT-technology made it likely that DME would face problems related to the cleaning of the biomass-based synthetic gas. These bottlenecks are likely to explain why DME did not receive continued support in the Netherlands.

Another promising technology that appeared during this period but was not part of the GAVE programme was the use of algae as biomass for the production of biofuels, energy or chemicals. This technology innovation arose in the 1980s. However, its high costs meant that the application of the technology was limited. In 2000, however, ECN decided to make a new evaluation of the technology by initiating the project 'Sustainable co-production of natural fine chemicals and energy from micro algae'. This project was subsidized by the EET programme from January 2000 until June 2003. ECN carried out the research in cooperation with: Agrotechnology and Food Innovations (ATO), part of Wageningen University; Koninklijke Sanders; CSK Food Enrichment; Essent Energy; Numico Research; Solid Chemical Solutions; IVAM, a research consultancy on sustainability; Techno Invent; and the research institutes UvA-IBED-Aquatic Microbiology; Kluyverlaboratorium for Biotechnology at TUDelft; and Food and Bioprocess Engineering Group at Wageningen University. ECN argued that the benefit of using algae as biomass was the opportunity to clean waste water in the process of cultivating and converting the algae to biofuels and related chemical products. Potential biofuels produced from algae were biodiesel, ethanol and methane. However, ECN

[32] The Waste Processing Corporation (Gemeentelijke Dienst Afvalverwerking, GDA) of Amsterdam is now known as the Amsterdam Waste and Energy Company (Afval Energie Bedrijf).

used its project time to research the production of chemicals instead of biofuels, due to the common assumption that the process of producing energy carriers from algae was too expensive because of the high cost of producing algae biomass (Reith, 2004).

In addition to all the advanced biodiesel projects financed, the GAVE programme funded bio-hydrogen development for use in the transport sector (Bosch, 2002). Private sector R&D initiatives in the field of bio-hydrogen were also forming, such as a cooperation between Shell and Daimler Benz (ANP, 1998). However, the hydrogen alternative remained at the periphery of the biofuel development trajectory, which is why the hydrogen case is not outlined in detail here.

4.1.4. SNM analysis, 1998-2002

Biofuels	**1998**	**1999**	**2000**	**2001**	**2002**
Conventional					
Biodiesel					H&R boats ≈14
	P. Friesland boats 7				P. Friesland boats 7
	Kooij & Plas boats 6				
PVO					Venlo vehicle 1
Advanced, R&D					
HTU fuel	Biofuels B.V./TNO	Pilot plant			
FT-diesel fuel				TNO-MEP	
				SDE	
				BTG, Shell	
Cellulose Ethanol fuel			Nedalco		
					Shell-Iogen

Table 4: Biofuel experiments, 1998-2002

Ethanol

Network actors	**Biofuel**	**Expectations**	**Key experiments**	**Learning**	**Socio-technical configurations**
No visible network	Ethanol	No articulated expectations	No experiments. The failure to build ethanol plant resulted in the withdrawal of granted funds and the technology disappeared in this period.	Industry in need of great funding for commitment	Niche not visible

Throughout this period, ethanol actors and their experiments were absent from the conventional biofuel niche. This can be explained by the failure to build an ethanol plant, due to the last minute withdrawal of key industrial actors which argued that government funding was insufficient.

Biodiesel

Network actors	Biofuel	Expectations	Key experiments	Learning	Socio-technical con-figurations
Municipality, province, boating companies, farmers' organizations. Province of Friesland leading actor. Number of actors temporarily reduced, but collaboration with other biofuels (PVO) increased	RME, pure use in boats, widened to agricultural vehicles	Rather simple technology which would create business opportunities for farmers, emission reduction mainly local connected to waterways, but increasingly global.	Discontinuation of tax exemptions led to a pause in experiments. Only Amsterdam trial carried on as a result of other pre-existing tax benefits.	Pure RME works. Initial problems with new diesel engines. Financing necessary for niche expansion	The Amsterdam boating fleet became a very small market niche. All other trials dependent on funding.

In the biodiesel *network* similar actors were involved as in the previous period, i.e. boating companies, farmers' organizations, a fuel importer and local authorities. However, with the termination of the temporary tax exemption in 1998 all the trials were ended apart from a waterbus trial in Amsterdam that already enjoyed tax advantages which made biofuel tax exemptions redundant. Despite the loss of tax exemptions, the province of Friesland took the network lead and managed to gain a new exemption for 2002-2005, which led to the return of actors and the restart of trials.

As in the previous period, network actors expected biodiesel to bring environmental benefits and business opportunities, in particular for farmers. During this period, actors' environmental expectations focused increasingly on global emission reductions as well as the local emission reduction voiced in the previous period. Although experiments with new diesel engines resulted in negative lessons, the majority of experiments with old diesel engines delivered positive lessons that confirmed expectations that biodiesel works and delivers positive emission reductions. The positive lessons together with a strong network leader contributed to the fact that biodiesel expectations were kept alive despite limited government support.

Biofuel experiments were more or less absent in this period due to the lack of government tax exemptions. Nevertheless, the Amsterdam boating trial continued, which implies a small and very limited biodiesel market niche. Other boating entrepreneurs restarted their biodiesel experiments once tax exemptions returned.

PVO

Network actors	Biofuel	Expectations	Key experiments	Learning	Socio-technical configurations
Entrepreneurs Abersons, leading farmers' organizations (NLTO), province. Increased collaboration within network and with biodiesel niche	PVO use in diesel vehicles	Future for farmers, emission reductions mainly local but also global. High expectations, partly thanks to good experiences from Germany and expected future tax exemption	Trial with conversion of vehicles, fleet trial in Venlo with sweepers both successful and led to long-term tax exemption	PVO works, Tax exemption necessary for niche expansion	A technology niche that was growing thanks to external pressure (biofuel directive)

New biofuel *actors* entered the stage during this period: the PVO actors. The leading network actors were the Abersons. They planned a larger trial involving a PVO mill in collaboration with farmers' organizations, regional development actors and municipalities. Eventually, the Abersons gained a tax exemption for the period 2002-2005. While network support was initially limited and weak, the tax exemption led to a swift widening of the network to include potential producers and users of PVO.

Like biodiesel, actors expected PVO to bring environmental benefits in the form of emission reductions as well as economic benefits for farmers and other regional actors. In the case of PVO, expectations also involved a move towards fuel self-sufficiency and reduced dependence on imported oil, which was a new biofuel expectation. Positive *lessons* from the PVO forerunner, Germany, kept expectations high and contributed to niche development.

These positive expectations together with strong network leadership by the Abersons and a government tax exemption contributed to an emergent PVO niche in 2002. The niche involved the conversion of vehicles to PVO propulsion by the Abersons and the start of a small vehicle trial by the municipality of Venlo, which expected to use domestically produced PVO in the near future.

Advanced biofuels

Network actors	Biofuel	Expectations	Key experiments	Learning	Socio-technical configurations
Scientists, scientific institutes, industry, Novem/GAVE	Fischer Tropsch, HTU, cellulose ethanol	Benefit global environment, increase energy and cost efficiency, contribute to economic growth	FT diesel experiments greatest promise, but fail. HTU gains additional support and pilot in Apeldoorn is realized.	Failure to set up the combined conventional and cellulose plant as well as FT diesel pilot led to realization that development was increasingly complex and more costly than first expected	FT diesel, HTU and ethanol remained R&D niches.

In this period, the main *network actors* in the advanced biofuel network were still scientists, research institutes and industry. An additional actor was the government agency responsible for running the GAVE programme, the first biofuel support programme. A new fuel, FT diesel, gained the most attention. However, at the end of the period many actors withdrew from FT projects, a collaboration between FT-diesel and the old pyrolysis technology was sought and the government agency turned its attention to HTU instead, which was the only technology that advanced during this period. Ethanol actors remained at the periphery throughout this period. With the entry of FT diesel and a government agency, the initial network developments showed expansion and increased width. However, at the end of the period some network actors withdrew their commitment to the network, particularly industry.

The network highlighted that advanced fuels would be both cheaper and more efficient at reducing CO_2 emissions compared to conventional biofuel in the medium to long term. This contributed to expectations that advanced fuel development would be a great business opportunity. Initial assessments confirmed the expectation from the previous period that cellulose ethanol was the advanced fuel closest to commercialization. A novel expectation for this period was the promise of FT-diesel as the second best option, with the best fit with conventional engine technology and fuel infrastructure.

Lessons from the initial studies enforced the expectations of advanced biofuel, by indicating that the medium-term demonstration and commercialization of both ethanol and FT diesel could be achieved within the GAVE programme. However, failure to build the combined conventional and cellulose ethanol plant granted funds in the previous period reduced expectations of ethanol in this period. Instead, FT-diesel gained centre stage. However, at the end of the period, the discovery of technical and institutional barriers led to declining FT diesel expectations and actor support. However, learning on HTU technology resulted in a test installation, reinforcing both expectations and actor support.

The evolution of networks, lessons and expectations led to the introduction of a new advanced biofuel in the R&D field: FT-diesel. The ethanol actors failed to build up serious R&D activities, while the existing HTU R&D niche advanced by delivering a test installation. The initiation of a biofuel support programme, GAVE, that reserved funds for advanced biofuels alone aided developments greatly in this period.

4.2. COMPETING BIOFUEL DISCOURSES, 1998-2002

4.2.1. General policy developments

At the EU level, the conventional biofuel discourse was growing in popularity. This popularity was related to general discourse changes, such as the increasing urgency in the environmental discourse to reduce CO_2 emissions and the re-emergence of the oil saving discourse. The urgency of CO_2 emission reductions was a result of the Kyoto Protocol, agreed in 1997, according to the agenda of the Rio conventions. The purpose of the Kyoto protocol was to mitigate various greenhouse gases by an average 5% reduction in relation to 1990 levels by 2008-2012. That the EU was the first to sign the Kyoto Protocol demonstrates the priority it gave to CO_2 reduction (IPCC, 2004). In its White Paper, *Energy for the Future: Renewable Sources of Energy* (EC, 1997), the EU showed its determination to meet the targets outlined in the protocol. One of the means to reach the CO_2 reduction target was to decrease the production costs of biofuels by giving general tax exemptions and additional subsidies for the cultivation of energy crops for biofuel production. An additional argument used to explain support for biofuels was the dependence on energy imports from increasingly politically unstable regions (EC, 1997). In this way, the EU referred to both the environmental discourse and the oil substitution discourse to gain increased legitimacy for biofuel development and implementation. The re-emergence of the oil substitution discourse in the biofuel debate can be traced to what Tatom (1993) refers to as the surprisingly large negative economic effects caused by the brief oil shock of the early 1990s. This oil shock was a result of Iraq's occupation of Kuwait and the Gulf War that followed. Concern over oil saving increased after the terrorist attacks on the USA in September 2001 and the 'war on terror' that followed. Despite the emphasis on environmental benefits and oil saving, a significant change in the EU biofuel lobby was the lack of references to the main biofuel lobby group – farmers.

According to the Kyoto Protocol, the Netherlands had to reduce CO_2 emissions by 6% on 1990 reference values by the period 2008-2012. To reach this target, the Dutch government set a national target that 10% of energy would be from sustainable sources by 2020 (Van den Heuvel et al., 2000). Before this target, Dutch CO_2 emission reduction activities and sustainability policies had only focused on energy saving and the generation of sustainable electricity (Little, 1999). To be able to reach the new targets the Ministers of Housing, Spatial Planning and the Environment and Economic Affairs recognized the need to broaden their CO_2 reduction activities. A new subsidy programme, GAVE, was set up in order to stimulate and speed up the market introduction of advanced biofuels and energy options (Van den Heuvel et al., 2000). Subsidies for conventional biofuels were more or less absent during this period.

4.2.2. Conventional biofuels

The lack of development of conventional biofuels was due not only to the emergence of a successful and competitive discourse, the advanced biofuel discourse, but also to developments in the conventional biofuel discourse. One example is the loss of the most successful lobby group in the biofuel coalition, the proponents of ethanol.

The ethanol lobby gained funds and a long-term tax exemption to commercialize conventional ETBE production and develop cellulose ethanol production, but Nedalco terminated the project. According to the Biofuel project manager at Nedalco (personal communication, 18.10.2005), the project failed because Nedalco's partners withdrew at the last minute. They found the investment capital and the production quota too small to be commercially interesting (ibid.). The inability to deliver the project, to live up to expectations, seems to have hit the ethanol lobby hard, and the lobby was no longer visible in media. As is shown below, Nedalco continued to search for new allies and new funding in the field of cellulose ethanol. Nedalco's choice of advanced ethanol process was not surprising given the growing status of the advanced biofuel discourse. Nonetheless, despite stagnation, there was still hope for conventional biofuels. The biodiesel lobby was still active and new biofuel proponents, a PVO lobby, was slowly emerging.

Although the biodiesel boat experiments ended in 1998 due to the lack of continued funding, selected actors from the Province of Friesland took the lead in the biodiesel coalition (Evers, 1998; Hettema, 1999). The Province saw the potential to set an example of biodiesel development (Hettema, 1999). It argued that continuing the project by its own means and gaining tax exemptions to stimulate others to join the project would make Friesland a role model for sustainable development (Volkskrant, 1999). The reference to sustainable development shows that the discourse was attempting to maintain linkages with the environmental discourse. Moreover, given the leading role of the Province and the motives for involvement in biodiesel development in the previous period, the potential contribution of biofuel development to regional development is likely to have played a central role in the discourse.

According to Pennewaard (1999), the Province was denied funding by the Ministry of Agriculture, Nature and Food Quality. The Ministry based its rejection on an evaluation published by Novem in 1998, which once again argued for support for bioenergy rather than conventional biofuels due to its better environmental and economic gains. The Secretary of State for Agriculture argued that he would only agree support for scientific research that gave new insights into the effectiveness of biodiesel, not field trials (Pennewaard, 1999). Hence, the statement in the 1993 Energy Policy that the government would only support biofuel R&D was still in force at the turn of the century. Despite this rejection, Friesland did not give up. The biodiesel coalition applied the same strategy as in the previous period; it turned to members of parliament for support. The Province managed to get a member of parliament, Crone, representing the Labour Party (PvdA), to introduce a bill on a biodiesel tax exemption (Vanlierop, 2001). The main argument in the bill was the ability of biodiesel to reduce pollution of the local environment, in particular the pollution of waterways as was referred to as in the previous period, but also for agricultural vehicles (Crone, 2001). Hofstra, a member of parliament representing the Liberal Party (VVD), was also approached. Hofstra had already tabled a bill in parliament requesting a tax exemption for PVO in road vehicles (Pennewaard, 2000b). Crone and Hofstra collaborated on both bills (Crone, 2001; Hofstra, 2001). The timing, the selection of members to approach and the collaboration of these members indicate potential collaboration between the biodiesel and the PVO coalitions.

Inspired by positive experience of PVO production and use in Germany, the main PVO coalition actors, the Abersons, started lobbying for financial support to build a Dutch oil mill for PVO production. Their discourse on PVO development referred to safeguarding the environment and creating reduced dependence on fossil fuels through local PVO production and use (Bijlsma, 2002b). This indicates their attempt to embed the PVO discourse in the environmental and oil saving discourse, following a similar strategy as the EU biofuel discourse. A central lobbying partner for the Abersons on their oil mill project was the farmers' organization NLTO (Bijlsma, 2002b). This involvement indicates that farmers' livelihoods and regional development seem also to have been fairly central for the PVO coalition.

As in the case of biodiesel, the Abersons failed to obtain funding in a direct request to the government and chose a strategy of approaching members of parliament. As is mentioned above, the strategy of the PVO lobby resulted in the introduction of a bill on PVO tax exemptions by Hofstra, which was followed by a bill from the biodiesel lobby for biodiesel tax exemptions (Solar Oil Systems, personal communication, 18.06.2007). Hofstra's bill, sent to the parliament with the support of Crone and others, referred mainly to the positive environmental impact of using biofuels in general and PVO in particular. He also referred to the fact that other EU member states already had general or partial tax exemptions for biofuels as an argument for a general tax exemption for PVO. In addition, Hofstra referred to boats and agrarian vehicles as potential biofuel fleets (Hofstra, 2001).

The Secretary of State at the Ministry of Finance, Bos, was hostile towards these bills because of the lack of interest in the transport sector in alternative fuels and the need for extended engine adaptations when using PVO. Bos also argued that strict EU regulations would not allow the long-term exemptions requested for both biofuels (LC, 2000; De Jong, 2001). In the light of the long-term ethanol tax exemption agreed by the EU in 1998, and Hofstra's presentation regarding biofuel tax exemptions in EU member states, Bos' argumentation indicates resistance to supporting biofuel. However, he could not do much to prevent the tax exemption once Crone's and Hofstra's bills gained majorities in parliament. According to Solar Oil Systems (personal communication, 10.10.2005), the majority for the biofuel bills in parliament was partly because both Crone and Hofstra represented parties in the current governing coalition.

Nor was Bos right with regard to the tax exemption. PVO was not widely accepted in the EU, which meant that the PVO actors had to continue lobbying at the EU level to gain formal acceptance for the long-term tax exemption, but the agreement of the EU was given a few months later (Bijlsma, 2002b; Bijlsma, 2002c). I explain the roles of the EU and the PVO coalition in more detail below.

That the EU was a great promoter of biofuels was already clear from its 1992 agricultural policy, which allowed temporary tax exemptions for biofuels in order to support farmers' livelihoods. As is mentioned above, there was a change of motives in 1997, when the EC suggested that member states should support biofuels for the transport sector in order to reduce CO_2 emissions and dependency on oil (EC, 1997). The White Paper, *Energy for the Future: Renewable Sources of Energy*, published in 2000, was even more persuasive with regard to the role of biomass as one of the means to reduce both CO_2 emissions and oil dependency. Biofuel in particular was seen as important in the transport sector, because the transport sector represented as much as 32% of energy consumption and 28% of the CO_2 emissions in the EU. The White paper even claimed that the current limit on tax exemptions to small-scale trials had been counterproductive to the needs of biofuel development. The EC set out the potential to achieve a 20% share for biofuels and other renewables in the transport sector by 2020. Consequently, the European Commission wished to promote biofuels by regulatory and financial means in order to boost implementation in all EU member states (EC, 2002; Van Thuijl, 2003). The debate subsequent to the White Paper led to the publication of two proposals for directives on the promotion of biofuels in June 2001. The first proposal was to oblige member states to implement a 2% share for biofuels on the fuel market by 2005 and 5.75% by the end of 2010. The second proposed directive allowed member states to give tax exemptions on biofuels. The authorization of a tax exemption was agreed, but the obligation to implement a target percentage for biofuels on the market was contested. The only countries that seemed to be in favour of such an obligation were Austria, Spain and Italy. The proposal was further criticized for limiting the choice of climate neutral fuels to biodiesel and ethanol (Van Thuijl, Roos, & Beurskens, 2003). Additional criticism came from the European Environmental Bureau (EEB), which was already critical of EU support for biofuels as part of CAP reform in 1992. Criticisms by the EEB (2002) of the draft version of the Biofuel

Directive was in a similar vein as in 1992, when it highlighted the negative effects of intensive farming practices on the local environment and biodiversity. In addition, the 2002 critique from the EEB saw greenhouse gas reduction from agricultural biofuels as uncertain and promoted further exploration of second-generation alternatives:

> Biofuel plantations require intensive farming with high-chemical input, will use large amounts of land, will burden soil and groundwater, and will decrease biodiversity. Regarding climate change, the benefits are very uncertain and the reduction costs are high. Therefore, the proposal does not make much sense, neither from an economic, an energy, nor an ecological point of view. The EEB thinks it is much more rational to promote promising and innovative technologies to convert organic waste from the agriculture and forestry production chain into biofuels […] (EEB, 2002)

There may have been many actors resisting legally binding targets, but it was only environmental organizations that were against the exploitation and use of conventional biofuels. In fact, there was a general acceptance of the use of biofuel in the European Union, as reflected in the three examples below. First, that the majority of the member states agreed a general biofuel tax exemption. Second, according to the EC (1998), a mix of 5% ethanol or 15% of the additive ETBE was allowed in gasoline fuel in 1998 (ibid.). Third, a variety of car manufacturers had started to make some of their diesel models compatible with biodiesel and a standard for biodiesel, so-called FAtty Methyl Esters (FAME), was under development at the European Committee on Standardization (Van den Broek, Van Walwijk, Niermeijer, & Tijmensen, 2003).

In response to the criticisms, the European Commission modified its proposed Directive in September 2002, presenting a broader definition of biofuels that included hydrogen. The commission also indicated that additional fuels might be included if they proved sustainable. The implementation of biofuel remained mandatory, but member states had the right to apply for dispensation in case of difficulties (Van Thuijl et al., 2003). The dispensation would only be for two years (GAVE, 2002b). Nonetheless, it would take until March 2003 before the final version was agreed. We return to the Biofuel Directive in chapter 5.

The growing biofuel discourse at the level of the EU from 1997 onwards is likely to have stimulated entrepreneurs to continue lobbying for tax exemptions despite the reluctance and negative opinion of first-generation biofuels held by the Dutch government and the scientific community. The Dutch government not only resisted the binding biofuel implementation target, like most other EU member states, but also resisted the widening of the tax exemption. Moreover, it is interesting to note that the environmental organizations at the EU level, including national representatives such as the Milieudefensie and Stichting Natuur en Milieu from the Netherlands, were against further support for biofuels, particularly given that the strongest argument used for the support of first-generation biofuels at the EU as well as the national level in this period was CO_2 emission reductions.

While the EU influenced national lobby groups and policymaking, the first-generation biofuel lobby also influenced EU policy. This was particularly obvious in the PVO case. According to an informant at Solar Oil Systems (personal communication, 10.10.2005), the Abersons were one of the stakeholders that helped to ensure that PVO was included in the Biofuel Directive. As is mentioned above, one of the criticisms of the first draft of the Directive was its focus on fuels such as biodiesel and ethanol, while neglecting other renewable fuel options. In collaboration with other PVO promoters, Aberson criticized this narrow selection of biofuels and convinced the EU to include PVO:

> [Aberson] was there when the preparations were made for the set up of the Biofuel Directive in Europe. It led to the fact that also PVO was mentioned as prominent, with plus points! This is because it was seen as the cleanest fuel that can be produced with limited financial means. (Solar Oil Systems, personal communication, 10.10.2005, translation by the author)

It also explains why the Abersons had to wait for EU consent before the PVO exemption was granted by the Dutch government.

The tax exemption granted for biodiesel was valid from 2002 to 2005 and supported the boats from the Province of Friesland as well as those from two local boat rental companies. At the same time, the farmer organization, NLTO, started to investigate the possibility of cultivating rapeseed in the Netherlands to feed the boating experiment with domestic biodiesel (DE, 2002b).

In the case of PVO, the tax exemption allowed the production of 3.5 million litres of PVO from the planned oil mill in the period 2002–2010 (Bijlsma, 2002b; Bijlsma, 2002c). However, investment in the construction of the oil mill fell through and the PVO coalition asked for help. The Ministry of Finance remained sceptical about PVO as a biofuel option. In addition, Novem did not want to contribute due to its new focus on second-generation biofuels, which it believed promised higher potential CO_2 reductions. The only political actor positive about PVO was the Ministry of Housing, Spatial Planning and the Environment (Bijlsma, 2002c). However, unlike the Ministry of Finance it could not grant government funds (Solar Oil Systems, personal communication, 10.10.2005). Consequently, by the end of 2002 the PVO project had made no progress.

Despite the above, support for first-generation fuels was growing at the end of this period. The media was reporting increasingly positive experiences of PVO from Germany and from the experiments in the Netherland (Bijlsma, 2002c). Moreover, once it was clear that the EU wished to support the implementation of biofuels by means of a general tax exemption, the majority of the lower house made it clear that it wanted to implement a general tax exemption on biofuels as soon as possible. According to the Ministry of Finance, this was not possible before the EC issued its revised Directive on mineral oil tax, which was expected in 2004 (DE, 2002a). At the same time, however, studies carried out on environmental policy by the National Institute of Public Health and the Environment (RIVM) in cooperation with the consultant bureau, Ecofys, showed that the implementation of the upcoming EC biofuel policy, including the mandatory targets, had the potential to increase the feasibility and acceptance of national environmental policy. The potential benefits to the Dutch government were cost reductions and the creation of a level playing field across the EU (Honing, Voogt, Harmelink, & Duvoort, 2002).

4.2.3. Advanced biofuels

As is explained in the section on the previous period, a few scientists within the bioenergy discourse started to promote the fitness of process technologies to applications in both bioenergy and second-generation biofuels. Hence, support for advanced biofuels was emerging, albeit on a limited scale. The increased popularity of advanced biofuels and the development of a discourse separate from bioenergy were linked to developments in general discourses in society. As is explained in the introduction, increased urgency with regard to CO_2 emission reductions and oil dependency contributed to the setting up of the GAVE programme to stimulate and speed up the market introduction of second-generation biofuels and advanced bioenergy.

Already in 1997, a budget of € 18.1 million had been set aside for GAVE. In addition to the potential CO_2 reductions, ministries saw potential benefits for the Dutch economy and businesses that already had a focus on oil products and natural gas, and could therefore profit from 'complementary activities' (Van den Heuvel et al., 2000: 5). The global environmental discourse seems to have been the main discourse used to motivate biofuel development at the national level. At the same time, however, advanced biofuel coalition actors used a new discourse to motivate development – the discourse of innovation and economic growth.

The GAVE programme only granted support to novel and advanced biofuels because of the preconditions set for the programme by Dutch Ministries. Their programme should support gaseous and liquid options with a CO_2 reduction potential of 80% or more compared to that of fossil fuels and the potential to be commercialized between 2010 and 2015. Those advanced biofuels eligible for funding were defined based on an evaluation before the programme (Little, 1999). The focus on R&D options and high environmental gains was in line with 1990s government policy, albeit more extreme. Moreover, it followed all the recent scientific studies, such as the LEI study (Van Onna, 1991), the Novem 1992 study (Lysen et al., 1992), the CLM 1996 study (Van den Heuvel & Kwant, 1996) and a Novem study by De Jager et al. (1998), which had estimated the potential for CO_2 reductions from conventional biofuels as particularly low. De Jager et al. (1998) even concluded that there was no cost reduction potential for conventional biofuels, while for novel and advanced biofuels there was potential in the long term (2010 and beyond) and a need for further examination. Seen in this context, the criteria set for the GAVE programme are likely to have been a conscious decision to exclude conventional biofuels from funding. This indicates that not only scientists, but also government actors had become advocates for advanced biofuel development.

While promises for novel and advanced biofuels were emerging, the general picture of biofuels that government reports and scientists had mediated until now had been negative. According to the coordinator of the GAVE programme at that time (personal communication, 05.10.2005), the negative image of biofuels did not work out very well for the programme. Consequently, they redefined biofuels into two types – conventional biofuels as 'first generation'. and novel and technically advanced biofuels as 'second generation'. In this way, the government agency coordinating the GAVE programme managed to link the negative connotations to conventional biofuels alone and create an opportunity for a positive image of novel biofuel options, thereby legitimizing the funding of advanced biofuel options.

That second-generation biofuels were the better biofuel alternative was a central argument in the discourse. Additional features were that the potential for CO_2 reductions from selected biofuels was large and the relative costs low. This was argued by Little (1999) in a report prepared for the GAVE programme. While government and scientific actors stood behind this discourse and supported the introduction of second-generation biofuels, they still shared the opinion that bioenergy was more efficient with regard to energy production (Van den Heuvel et al., 2000; see also De Jager et al., 1998).

While the bioenergy discourse was stronger than the second-generation biofuel discourse, a setback in bioenergy development in the late 1990s contributed to the development of the advanced biofuel discourse. This setback was the failure to deliver waste gasification projects for energy production within the bioenergy discourse. According to Raven and Verbong (2001), the increased price of waste feedstocks made the gasification technology expensive, which led core investors – the electricity companies – to pull out of the project in 1998. With the retirement of investors, the promise of gasification technology in the energy sector vanished (ibid.), forcing many scientists to search for alternative markets. Given that for strategic reasons many scientists had already promoted their process technologies as fit for both biofuels and bioenergy, the shift to promoting the technology process for biofuels alone is likely to have been fairly easy. The fact that vehicle fuels gained more attention as a result of the increasing focus on CO_2 reductions also contributed to the growing attention on advanced biofuels.

Eventually, after a great number of evaluations selecting the most promising options to fit with the criteria that the government had set out, the GAVE programme started in 2001 (Little, 1999; GAVE, 2001a; Van den Heuvel et al., 2000; GAVE, 2001a). The evaluations also led to a slight change in the objectives of the GAVE programme. In addition to the initial objective of facilitating market introduction, GAVE would aid the removal of technical barriers and enable the demonstration of entire chains of gaseous and liquid fuels before 2010 (Van den Heuvel et al., 2000).

In the organization of GAVE, it was not only the programme content that was novel, but also the programme policy. The GAVE programme followed a novel policy method – transition management (GAVE, 2001b). Transition Management was a policy practice introduced in 2001 by the new energy and environment policy (Natuur en Milieubeleidsplan 4, NMP4). Researchers and Ministries argued that current environmental problems could not be dealt with using existing policy instruments and practices, and therefore developed the transition management policy. They considered current environmental problems particularly complex due to their embedding in the societal system. This system innovation approach was suggested in order to resolve this. A system innovation is a long term societal transformation process, called a transition, which entails the coordination of socio-cultural, technological, economic and institutional change. In brief, this policy implies dealing with uncertainty of change by keeping options open to limit innovation lock-in, scenario building, long-term thinking, attention to the international context and finding solutions on a suitable scale. It is also necessary for government to steer and stimulate the above-mentioned processes (VROM, 2001: 74).

The NMP4 did not only influence the policy management of the GAVE programme. It seems to have contributed to a positive biofuel discourse and helped the GAVE programme to come about. The NMP4 (VROM, 2001) voiced the need for an energy transition towards renewable sources in order to combat the CO_2 emissions causing climate change. While the NMP4 recognized the shortcomings of biofuels, it recommended biofuel implementation due to the great CO_2 reduction potential.

> Alongside improving the quality of the current fuels, it is of great importance that alternative fuels, such as climate neutral biofuels and hydrogen, are used. (VROM, 2001: 98, translation by the author)

The recommendation referred to 'climate neutral biofuels' but did not specify which biofuels this meant.

Another motive for the NMP4 to promote biofuel implementation was to comply with the Biofuel Directive, which the EU was planning to implement. The expressed wish to meet the targets set by EU Biofuel Directive may have been the beginning of a cooperative rather than an antagonistic relationship between first- and second-generation lobby groups. This is due to the planned market implementation of biofuels by 2005, when second-generation biofuels were still only at the lab-scale. A report published by the ECN (Van Thuijl, 2002) supports this conclusion. Van Thuijl argued that conventional biofuels could serve as bridging technologies and should therefore receive government support. Van

Thuijl warned against too much promotion, however, since this might create a lock-in effect, and thus hinder the development of new, more sustainable biofuel alternatives (ibid.). This change indicates that the first-generation biofuel lobby was successful and that its discourse was expanding. This is likely to relate to the first-generation policy advances at the EU level as well as the tax exemptions granted to PVO and biodiesel at the national level in 2001. Nevertheless, we should not forget that the general opinion among scientists was still that only second-generation options should be promoted. A good example is the arguments by the energy researcher Faaij in an energy journal in 2001. Together with Daey Owens, Faaij was one of the few scientists to lobby actively for all second-generation biofuels. Others tended to lobby for one fuel option only. This was the same year the long-term tax exemption for biodiesel and PVO was granted, and could be seen as a reaction to the granting of this exemption.

In an interview in an energy journal (DE, 2001 p.38), Faaij explained that the cultivation of wood- and grass-based biomass for the production of biofuels in the transport sector was a much more efficient means to deal with CO_2 reduction and the depletion of fossil energy sources. Similar to what had previously been expressed by Daey Ouwens and biomass to electricity researchers, Faaij claimed that the mass subsidies going to rapeseed and sugar beet biofuels were only 'disguised price measures and income support for farmers. Political reasons that have little to do with the environment' (ibid., translation by the author). According to Faaij, better aid for these farmers would be financial and long-term policy support for 'new' energy crops, based on grass and wood. Faaij expected that these biofuels would substitute for fossil fuels in the transport sector in the future. The next step, according to Faaij, was a fuel cell car that ran on hydrogen produced by means of biofuels (bio-hydrogen). To manage more sustainable energy production in the long run, Faaij recognized the need to import biomass from developing countries. He claimed that the switch to biomass for electricity and biofuels for the transport sector created opportunities not only for local farmers, but also for developing countries.

Faaij argued that there was sufficient financing. The only problem was that it went to the wrong alternative fuels – first-generation fuels. In addition to embedding the advanced biofuel discourse in the global environmental and oil substitution discourses, Faaij's reasoning indicates attempts to link up with the farmers' livelihood discourse which was initiated in the previous period. However, the reference to second-generation biofuels as a means to further the economies of developing countries was new. The latter was contrary to the first-generation lobby, which directed its attention to support local farmers and local economies. Another novel argument presented by Faaij was the presentation of hydrogen as a logical step after second-generation fuels – indicating that a third-generation fuel discourse was on its way.

In September 2002, Van der Heuvel was one of the first political actors to point out the problems of reaching the novel policy goals set out by the EC in the Biofuels Directive. He sketched out the shortage of biofuel production in the EU by stating that biofuel's current share of the market was only 0.3%. Hence, Van der Heuvel argued that the new EU target of 2% biofuel implementation by 2005 was unlikely to be achieved. Furthermore, he argued that the conventional fuels would not contribute much to CO_2 reduction (GAVE, 2002c). Nevertheless, regardless of whether the targets were hard to reach, studies carried out on environmental policy by RIVM in cooperation with Ecofys showed that implementation of the upcoming EC biofuel policy, including the mandatory targets, had the potential to increase the feasibility and acceptance of national environmental policy. The potential benefits for the Dutch government were cost reductions and the creation of an level playing field across the EU (Honing et al., 2002).

With regard to the GAVE programme, the initial period (2001-2002) focused on research and the formation of alliances to enable market demonstrations in 2002-2008 (Tweede Kamer, 2002; EVN, 2002). In the field of second-generation biofuel technology, only the Fischer Tropsch fuel option was explored. Fischer Tropsch diesel, cellulose ethanol and HTU were considered the best biofuel technologies (Bosch, 2002; Little, 1999). After a year of evaluations, the project partners decided to terminate the two Fischer Tropsch projects. Various reasons were given, but it all boiled down to the fact that the technology was immature and had few commercial prospects compared to bioenergy (GAVE, 2002d; Jansen & Berends, 2002).

That actors withdrew from the project was surprising given the high expectations set out for FT-diesel. One possible reason behind the withdrawal was that the bioenergy discourse was still much stronger than the biofuel discourse. Another possible reason was that government subsidies were too limited. According to Daey Owens (2002), the scientific capacity to develop second-generation biofuels existed in the Netherlands, but it was not sufficiently supported by the government. As a result, the know-how was exported and the Netherlands lagged behind in the development of biofuels.

The failure of the Fischer Tropsch diesel projects gave the HTU lobby a chance to show its potential. A first demonstration was planned for 2007 (Knoppers, 2002). There is more on the GAVE programme below.

In sum, the wish to stimulate advanced biofuels options was expressed not only with the set up of the GAVE programme, but also in the Fourth National Environment Plan (NMP4) published in 2001. Unexpected health problems in the livestock industry contributed to additional policy change in the NMP4, which in turn created opportunities for biofuel development.

At the turn of the century, animal diseases increased in Europe. One example was Bovine spongiform encephalopathy (BSE), more commonly known as Mad Cow Disease or Creutzfeld Jacob disease when carried by humans. Another example was Foot and Mouth disease, which became common among cloven-hooved animals (Vis, 2006). Consequently, a new standard was set for animal feed. This was set out in new legislation adopted in 2001 and 2002, which prohibited the use of many animal-based and other organic by-products in feed (Vis, 2006; Elbersen et al., 2002). In the case of the Netherlands, the NMP4 set out a reduction of livestock content by 50% in the coming decades and prohibited the use of many by-products (potato peel, molasses, etc.) previously used as animal feed. While these organic by-products were increasingly used as feedstock by energy producers, there was also an increased interest in using oil-, sugar- and starch-related waste and by-products for the production of biofuels (Elbersen et al., 2002; Den Uil, Bakker, Deurwaarder, Elbersen, & Wiesmann, 2003). Some of these products, such as waste products from the wheat and sugar processing industries, had been used by Nedalco since the early 1990s (Den Uil et al., 2003). With the exception of Nedalco, however, using waste as feedstock had mainly been part of the bioenergy and advanced biofuel discourse (see Raven & Verbong, 2001). As a result of the NMP4, funding was granted by Novem through various subsidy programmes to explore the potential for using the new biomass streams in a variety of electricity routes, but also in biofuel routes.[33] The biofuel routes suggested included conventional ethanol for sugar and starch

[33] Research was funded via the DEN (Sustainable Energy Netherlands), EOS: NEO (the Energy Research Subsidy focusing on New Energy Research, e.g. inventions and ideas) and the EET (Economy, Ecology and Technology) programme.

processing, cellulose ethanol, HTU and novel processes such as biodiesel production from animal fats. Nevertheless, the studies were only summaries of possible electricity and biofuel routes. No significant policy suggestions were made that would stimulate further development (GAVE, 2002a; GAVE, 2002d; GAVE, 2003c). The fact that the use of biomass waste had been identified within the bioenergy discourse and later in the second-generation biofuel discourse puts this experimentation with both advanced and conventional biofuel routes in a somewhat ambiguous position. Conventional technologies, such as biodiesel processing from waste oil, later identified themselves with the second-generation biofuel discourse in order to gain more legitimacy and support.

4.2.4. Discourse analysis, 1998-2002

Policy	Level	Year	Type	Size	Description
General					
Directive Proposal	EU	2001	Regulation proposal		Obligation to implement 2% in 2005 and 5.75% in 2010
Advanced biofuels					
GAVE programme	Government	1999-	R&D	M	Large-scale programme of research and field trials with gaseous and liquid biofuels. FT-diesel and HTU supported.
EET programme	Government	1996-	R&D	S	Economy, Ecology and Technology R&D programme. Ethanol and HTU projects supported.
Conventional biofuels					
Biodiesel H&R	Government	-1998	tax exemption	S	2 years for 70-108 boats
Biodiesel Friesland	Government	2002-2005	tax exemption	M	3 years for about 77 boats
PVO Aberson	Government	2002-2010	tax exemption	M	8 years for PVO mill and vehicle market.

Table 5: Biofuel policy, 1998-2002

Conventional biofuels - biodiesel and PVO discourse (first generation)

Biofuel	Discourse	Mobilization/ impact of wider discourses, events and policies	Discourse coalition	Target audience	Key activities, strategies	Resulting space/ policy creation or disruption
Biodiesel and PVO pure use and production. Conventional ethanol discourse not visible in this period	Both PVO and biodiesel as a means to produce mainly local but also global environmental benefits and aid regional development. PVO was also argued to be less expensive than refined biodiesel.	Embedding was sought in environmental discourse as well as regional development discourse that was replacing the farmer livelihood discourse. Both PVO and biodiesel were seen as means to reach planned EU policy targets.	The ethanol lobby left the scene temporarily and was replaced by biodiesel and bio-oil promoters. These were farmers' organizations, Province of Friesland, politicians, entrepreneurs such as Abersons.	Biodiesel coalition had government as audience while PVO coalition sought support from both government and EU to gain tax exemptions	Lobbying for tax exemptions to expand trials. Lobbying took place in media and in national and EU parliament. The reference to regional development instead of farmer livelihood was a strategy to avoid previous critique of biofuel as just farmer support	Pause in new biofuel tax exemptions, but high expectations for future support as a result of upcoming EU policy keep activities going. Tax exemptions restart in 2002 (-2005 for biodiesel and -2010 for PVO) as a result of EU policy, lobbying and failure to develop advanced biofuels in the short term.

In the biofuel discourse the environmental gains from using biofuels were still referred to. In the words of Aberson 'it [PVO] was seen as the cleanest fuel that can be brought about with limited financial means'. However, the national level focus remained on local emission reductions while the EU paid increased attention to global CO_2 emission reductions. A main reason for this was the withdrawal of the ethanol actors from the biofuel coalition during this period, which had previously promoted CO_2 reduction. Coalition actors increasingly widened their references to biofuel as a means to support farmers' livelihoods and biofuel as means for regional development at both the national and the EU levels. A new element in the discourse was the increased reference to biofuel as a means to reduce oil dependency. Another, less prominent, element of the discourse was the relatively low cost of fuels such as PVO, as is indicated in the quote above. While the conventional biofuel discourse was embedded in many general discourses, the failure to successfully embed it in the increasingly CO_2-oriented environmental discourse was decisive for the lack of tax exemptions between 1999 and 2001. According to government policy, biofuels with large CO_2 reduction potential, such as second-generation biofuels, were the only ones to be funded. At the end of the period, once the need for short-term implementation became urgent as a result of the upcoming EU biofuel Directive and failed second-generation projects, tax exemptions were granted to biodiesel and bio-oil.

The ethanol lobby, which had dominated the conventional biofuel coalition in the previous period, failed to set up the planned production plant and left the scene. Instead, biodiesel and bio-oil promoters dominated the biofuel coalition, mainly represented by a local authority and single entrepreneurs in the north of the Netherlands. While the coalition was weak, single entrepreneurs kept the discourse alive by means of strong lobbying activities. Their strategic coordination in lobbying for a tax exemptions at the parliamentary level eventually contributed to the granting of tax exemptions for both biodiesel and PVO at the end of the period. In the PVO case, additional lobbying activities at the EU level proved necessary since it was not a generally accepted biofuel. An additional strategy initiated in the previous period was to change the focus from biofuels as a means to aid farmers' development to regional development in order to avoid criticisms that biofuel was only a means to support farmers' interests.

In this period, the government initially halted the granting of new conventional biofuel tax exemptions. The first large-scale ethanol project that the government granted funding in 1997 did not take place. The emerging EU biofuel policy, along with strong lobbying, resulted in an eventual three-year tax exemption for biodiesel and an eight-year tax exemption for PVO. The fact that the main funds went to advanced biofuels instead of conventional fuels made advanced biofuels the main competitor of conventional fuels. This meant that that the previous competition with the bioenergy coalition was no longer central.

Advanced biofuels (second generation)

Biofuel	Discourse	Mobilization/ impact of wider discourses, events and policies	Discourse coalition	Target audience	Key activities, strategies	Resulting space/policy creation or disruption
Advanced biofuels	Advanced biofuel was seen as potentially the most efficient, cheap and environmentally friendly fuel for the transport sector in the long term. While conventional biofuels were still seen as only supporting farmers, advanced fuels could support economic growth nationally and abroad in developing countries.	Embedding was sought in the global environmental discourse, and the economic development (and innovation) discourse at a national and development cooperation level.	In addition to scientists and research institutes driving the coalition, a govern-ment institute joined, which increased the legitimacy of the discourse.	Government, general public	Lobbying against conventional biofuel support. Use of media and scientific publications. The main strategy was the argument of first- and second-generation fuels to distinguish advanced fuels and stress their superiority over conventional fuels.	R&D funds: GAVE and other less defined funding programmes

In this period, the advanced biofuels gained increased attention, which implies increased separation of the advanced biofuel discourse from the bioenergy discourse. Like the previous period, the discourse pictures advanced biofuels as potentially the most efficient, cheap and environmentally friendly fuel for the transport sector in the long term. In particular, the CO_2 emission reduction potential was stressed which was in line with developments in international environmental policy, such as the Kyoto Protocol, and the environmental discourse in which the advanced biofuel discourse was embedded. To stress the superiority of advanced biofuels, conventional biofuels were still criticized. In the words of a coalition actor, support for conventional biofuels was 'disguised price measures and income support for farmers'. Political reasons that had little to do with the environment'. A novel element was the reference to advanced biofuels as a means to create business opportunities and further economic growth in the Netherlands, for the Dutch petrochemical industry and farmers, but also in developing countries as potential feedstock providers. By these means, coalition actors sought embedding in the general economic growth and innovation discourse. At the end of the period, with increased pressure for short-term biofuel implementation caused by the emerging EU Biofuel Directive, the tone towards conventional biofuels became more accepting.

In addition to the scientists and research institutes driving the coalition, a government institute (Senter Novem) joined the promotion of advanced biofuels, which increased the legitimacy of the discourse. The discourse was also strengthened by the fact that many researchers in the bioenergy field changed their focus to biofuels when investment in the bioenergy research domain was reduced in the late 1990s. In line with the professions of coalition actors, lobbying measures relied on scientific publications and policy reports communicated to the government and through the media to influence public opinion and government policy. A successful strategy applied by the coalition to avoid the negative connotation previously given to biofuels by the bioenergy coalition, was the introduction of a new biofuel terminology – advanced biofuels were referred to as second-generation fuels, while conventional biofuels were referred to as first generation.

The result of coalition strategies in a wider context of changing discourses was the setting up of GAVE – the first biofuel development and demonstration programme with funds reserved for advanced biofuels alone. However, once it became clear that the GAVE programme would fail to deliver the advanced biofuel demonstration projects as planned, discourse support was reduced.

Despite the failure to reach the goals set out in the GAVE programme, the advanced biofuel discourse was strengthened in this period. A contributory factor to this positive development was its lack of competitors. The bioenergy actors were increasingly supportive of biofuels and the conventional biofuel discourse was weak at the national level.

4.3. CONCLUSIONS: BIOFUEL DEVELOPMENTS, 1998-2002

This section presents conclusions from two perspectives: an SNM perspective and a discourse perspective.

4.3.1. Biofuel niche conclusions

The difference in government financial support between conventional and advanced fuels noted in the previous period increased during this period. The government reserved the majority of its funds for the development and demonstration of advanced biofuel production, such as cellulose ethanol and FT diesel, and denied requests for new tax exemptions for conventional biofuels from 1998 to 2002.

Despite initially highly positive advanced biofuel expectations and growing network support, as well as large and more consistent government funds, the actors failed to meet expectations for the most promising fuel alternatives – cellulose ethanol and FT diesel. However, HTU, which was slightly less promising and had less actor support, showed more progress.

Even though the government prioritized funds for advanced biofuels and rejected new and follow-up tax exemptions for conventional biofuels, the conventional biofuel niche did surprisingly well. A small biodiesel market niche appeared and selected niche experiments managed to gain a longer term tax exemption by the end of the period. This was thanks to strong network leaders voicing positive expectations backed up by positive experience. The failure to deliver short-term development of advanced biofuels is also likely to have contributed to follow-up and more long-term funding for conventional biofuel in 2002.

4.3.2. Biofuel discourse conclusions

In this period, there was a polarization of the biofuel debate by the creation of a conventional (first generation) versus advanced (second generation) terminology. The latter was a strategy by advanced biofuel supporters to gain legitimacy for an advanced biofuel discourse separate from existing conventional biofuel and bioenergy discourses .

These strategies were aided by advanced biofuel coalition actors with a large degree of political influence, who presented a discourse that fit the general political agenda better than the conventional biofuel discourse. This was related to the strong embedding of the advanced biofuel discourse in an environmental discourse focused ever more on CO_2 emission reductions and the innovation and economic growth discourse. The latter in particular answered the needs of the petrochemical industry, which was a powerful actor that contributed greatly to the Dutch economy through the concentration of petrochemical businesses in Rotterdam harbour. The result was that the first biofuel policy measure, the GAVE programme, became oriented towards the development and demonstration of advanced biofuels.

Local political parties, entrepreneurs and farmers' organizations, as part of the conventional biofuel coalition, did not have the same power or influence as advanced biofuel coalition actors. This resulted in the government rejecting conventional biofuel tax exemptions for the greater part of this period. However, international political pressure in the form of an upcoming EU biofuel policy created urgency for short-term biofuel implementation. Together with a strategic alliance of conventional biofuel coalition actors with members of parliament, this resulted in longer term tax exemptions for a biodiesel and a PVO project in 2002.

5. FAST BIOFUEL MARKET IMPLEMENTATION AND STAGNATION, 2003-2010

This chapter presents biofuel developments in the period 2003-2010. First, I outline the development of the biofuel niche, followed by an SNM analysis. Next, I present the political processes leading up to biofuel-related policy measures, followed by a discourse analysis. A concluding section closes the chapter.

5.1. A BIOFUEL MARKET NICHE IN FLUX, 2003-2010

5.1.1. General policy developments

Various European Union and government policy measures stimulated biofuel developments during this period. At the EU level, the Biofuel Directive set an indicative target of a 2 per cent market share for biofuels by 2005 and a 5.75 per cent share by 2010 (EC, 2003a), and the Mineral Oil Directive was changed to allow member states to give general biofuel tax exemptions of six years or longer (EC, 2003b). As a consequence of EU policy, the Dutch Government changed the role of the GAVE programme from that of an R&D funding programme to assisting the government and related stakeholders to reach the EU's indicative targets (Tweede Kamer, 2005a). Moreover, the government set out a biofuel policy in 2005, which included a biofuel tax exemption for 2006 and an obligation on fuel distributors to distribute biofuels from 2007 (Tweede Kamer, 2005b). The budget for the 2006 tax exemption was estimated at € 70 million but, due to the limited extent of biofuel use, only € 20.3 million was used in the end (Van Gelder & Kroes, 2008). The intention of the one-year tax exemption was to aid and prepare the fuel sector for the obligation to distribute biofuel as a 2 per cent share of the total fuel distributed from 2007. In the years after 2007, the mandatory biofuel target would be increased incrementally in order to conform with the 2010 EU target (Tweede Kamer, 2005b: 20-21, 63; GAVE, 2005h). However, the biofuel targets were reduced, first at the national level (Cramer, 2008a) and later at the EU level (Harrison, 2008; EC, 2009).

5.1.2. Conventional biofuels

Ethanol

In the context of an EU Biofuel Directive and more encouraging policy at the national level, there was renewed interest in conventional ethanol use.

Rotterdam municipality led the main initiative aiming for a higher percentage of ethanol (E85) use in vehicles. The initial goal set by the municipality was to run 12 Flexi Fuel Vehicles (FFVs) on any mixture of gasoline and ethanol up to 85% ethanol (E85). The vehicles were delivered by Ford in 2005 for Rotterdam municipality's own vehicle fleet and the fleet of its vehicle-leasing partner, Roteb Lease. If the project was successful, the municipality planned to set up an ethanol filling station in Rotterdam in 2006. Vermie, the spokesperson for the project at the Municipality of Rotterdam, said that the purpose of the project was to spread ethanol use in the region (GAVE, 2005s). Roteb Lease, Nedalco, Ford and a small number of fuel distributors were part of the project, which was called 50 FFV vehicles Rotterdam. The ethanol project was embedded in a local renewable fuel project, Schone voertuigen Regiogemeente Rotterdam (Clean vehicles Region Municipality Rotterdam), which aimed to stimulate the use not only of ethanol, but also of biodiesel and hybrid vehicles. It was also embedded in the European project Bio Ethanol for Sustainable Transport (BEST) (GAVE, 2009f). Two Swedish partners, Stockholm City and the Swedish Biofuel Region, coordinated BEST, which ran from 2006 to 2009. Alongside Rotterdam and the Swedish partners were Madrid, La Spezia, the Basque Country, Somerset County, Nanyang and Sao Paolo. The aim of the BEST project was to explore infrastructure, and stimulate ethanol use in vehicles in the context of the European Union's strategy to reduce the consumption of fossil fuels and greenhouse gas emissions. The Swedish partners, which had long-term experience of ethanol vehicles, infrastructure and standards, provided advice and guidance for their European partners (BEST, 2010). In 2006, a trial involving six ethanol FFVs started in Rotterdam. In June the same year the first pump distributing E85 was set up by the oil distribution company Argos Oil to refuel the FFVs (BEST, 2006). In September, the municipal fleet had 20-30 ethanol vehicles. Vermie announced a target of 3000 ethanol FFVs by 2009 (GAVE, 2006c). In spite of the termination of the biofuel tax exemption, which meant that the price of ethanol became less competitive with gasoline after January 2007, Vermie reached this goal with interest. According to BEST (2009), there were more than 5000 FFVs in the Netherlands by January 2009. A contributory reason for this success was the ability to make a deal with Ford to offer some of their vehicles at a reduced price (BEST, 2010).

With regard to the expansion of pumps, the website Fuelswitch (2010) reports that there were 27 refuelling locations for E85 in the Netherlands by 2010. In addition to Argos Oil's E85 initiative, other fuel distributors introduced pure ethanol for FFVs in Rotterdam. One contributory factor was that Rotterdam municipality offered local subsidies for the installation of E85 pumps (BEST, 2010). However, other actors installed E85 pumps outside Rotterdam, sometimes together with other alternative fuels. One business idea in 2005 introduced by the consultant company Zero-e was 'refuelling islands' – small areas providing biodiesel, ethanol and natural gas at existing filling stations. Despite interest from the vehicle industry, technical suppliers and refilling stations, however, these were never realized (Bovag, 2005). Delta Oil was more successful at achieving multiple fuel distribution in the Newtonpark in Leeuwaarden. A fuel distribution station opened in February 2007, distributing E85, PVO and biodiesel. Distribution of natural gas and biogas was expected to start in the near future (GAVE, 2005g; Stichting Schoner Transport, 2007). The installation of additional ethanol pumps was stimulated by a new government subsidy for the construction of alternative refuelling stations, Tankstations Alternatieve Brandstoffen (TAB). In the first tender process in 2008, € 1.2 million was made available for ethanol and natural gas filling stations (V&W, 2008), which produced 69 ethanol fuel pumps (BEST, 2009). The second tender process in 2009 supported only three E85 ethanol pumps from a total subsidy of € 3.6 million made available for biofuels. Both national and regional authorities financed the second tender process. The majority of the funds went to biogas (SenterNovem, 2010b; Interprovincial Overleg, 2010). Of the E85 refuelling stations that were built at a later stage, the pumps set up by Tamoil charged the same price for ethanol as for gasoline, which was generally lower than the ethanol price set by other fuel distributors. This was achieved in collaboration with the Municipality of Rotterdam and the EU BEST project, with the intention of expanding the FFV market (BEST, 2010).

While previous attempts to implement ethanol vehicles had failed to establish a market niche in the Netherlands, the municipality of Rotterdam made a flying start in this period. This development is surprising considering the limited financial incentives. At the local level, the Rotterdam municipality, Tamoil and Ford were financial supporters. At the national level, there were only the TAB subsidy, the one-year tax exemption and a biofuel obligation. However, the obligation mainly promoted low blends. One factor that is likely to have contributed to the success was collaboration with experienced partners such as Ford and the various BEST partners, which meant that Rotterdam could rely on lessons learned from other large-scale international experiments.

The successful FFV vehicle implementation project and the rapidly increasing number of E85 fuel pumps meant an increased demand for ethanol. The Rotterdam trial saw the return of Nedalco to conventional ethanol projects after some years of absence. The EU Biofuel Directive stimulated Nedalco's involvement in conventional ethanol. According to Nedalco (2003), the Ministry of Economical Affairs and the Ministry of Housing, Spatial Planning and the Environment gave Nedalco the opportunity to set up a platform for ethanol development in 2003 within the new energy policy, the Energy Transition, in order to get the ethanol vehicle fuel market going (Nedalco, 2003). Nedalco's response was to set up the project Nederland Opweg Naar Ethanol (The Netherlands on the Road to Ethanol), more commonly known as Nr. One. The partners involved in the project were Nedalco, the Ministry of Environment, the research institutes ATO, LEI, TNO, TNO MEP and the research consultancy companies Bird Engineering and Belmont Innovaties en Management BV. The goal set was similar to that outlined by Nedalco in 1997: to start production of ethanol from waste materials based on starch and slowly transfer to ligno-cellulose biomass. The vision was to realize ligno-cellulose ethanol experiments by 2004-2005 and to have ethanol widely used as a climate neutral transport fuel and in the chemical industry by 2040 (Nedalco, 2003). This cooperation produced several research projects and novel findings in the field of advanced ethanol generation (see the section on cellulose ethanol below), but not much progress was made.

In the period 2002-2005, Nedalco repeatedly made statements about setting up an ethanol production factory with an annual capacity of 200 million litres. It argued that the factory would be the first large-scale ethanol production facility in the Benelux area. In 2004 Nedalco announced that Cerestar, a subsidiary company of the Canadian Cargill, would be a major partner in the project (GAVE, 2004e).[34] However, in 2007, the plan to build a conventional ethanol production plant with the potential for advanced cellulose ethanol production was replaced by plans to build an advanced cellulose ethanol plant from the start (Bouchie, 2007). According to an employee at Nedalco, Nedalco's reason for abandoning conventional technology in 2006-2007 was the inability of grain ethanol, even waste grain, to compete with sugar cane ethanol. This was due to the price of grain, which was increasing faster than the price of sugar cane. Even with EU import tariffs, sugar cane ethanol from Brazil was cheaper than grain ethanol (TNO, personal communication, 06.11.2008). Nedalco was unable to produce a competitive conventional ethanol fuel despite its reliance on waste wheat. This left only one option, to turn to cellulose ethanol and repeat the promise to deliver a cheap alternative in the future (see below).

Other entrepreneurs attempted similar local feedstock-based conventional ethanol projects to Nedalco. Some focused on a variety of waste products, not just waste grain, or on co-production solutions to cut production costs. However, they faced similar problems as a result of increasing feedstock prices. One example is a biorefinery project – the Groene Poort (Groene Poort, 2012). An ethanol plant, a wastewater plant and a biogas plant were to rely on local feedstock, such as bio waste from the large horticulture complex in Zeeland. The plants were to contribute to CO_2, energy, heat and fresh water for horticulture, as well as additional water, ethanol and biogas for external customers. The main project partners were the horticultural company Van der Lans and seven young agrarians (Jansen, 2008). Despite

[34] Cargill and Nedalco have been cooperating closely for many years. Cargill bought Nedalco from Cosun in 2010 (Cargill, 2011).

carrying out planning and evaluation since 2005, and the existence of additional project partners such as the Province of Zeeland and various government subsidies, the ethanol plans were put on hold in 2008 due to high feedstock prices. The current focus is on the biogas installation (Groene Poort, 2012).

Feedstock prices remained a problem. Another project, Green Co., which aimed to start ethanol production in 2008, is still on hold as a result of high food prices. This project was led by Nivoba, a company that specializes in the processing technology for starch, in collaboration with the environment technology company Oosterhof Milieutechniek B.V. and local farmers. For the rest they had similar project partners to the Leeuwarden project[35] (Province Drenthe, 2007; GAVE, 2012).

It was not only high feedstock prices that led to failed ethanol production projects. Criticism of the use of food crops is also mentioned as a reason for the failure to realize ethanol production as part of a larger biorefinery set-up by the Bio-ethanol Rotterdam B.V. (BER). BER was a company set up by two entrepreneurs, Van der Gaag and Aurich, in 2004. Their ambition was to produce biofuel with maximum energy revenue and zero emissions in order to improve air quality in the Rotterdam area. Zero emissions implied that the process would not rely on any fossil fuels. Like the plans of Nedalco, BER wanted to use low quality wheat not suitable for food production as a feedstock. BER was also using excess steam from other industries. Estimated annual production was 125 million litres of ethanol and 48 million litres of biogas. BER presented the biogas process as 'SuBERgas'. Examples of additional by-products were CO_2, bio-ammonia, digestate and 'green electricity' for industry in the harbour. The choice of location, Rotterdam, was related to easy access to cheap raw materials and markets for by-products and transportation fuels by the industries located around the harbour and the harbour itself (Gengler, 2008). BER had many partners that cooperated in realizing the project, such as the Chemical Processing Consult (CPC) and HES Beheer en Holland Innovation Team (GAVE, 2006b). Despite the promotion of this biofuel as more sustainable and cheaper than second-generation fuels, BER did not manage to raise funds (Gengler, 2008). According to BER's own website (BER, 2009), the ethanol project was put on ice due to growing criticism of the use of food crops as a feedstock for fuel, despite the choice of low quality wheat. However, the biogas project continued under the Energy Valley foundation. Energy Valley (2008) was a private-public cooperation set up in 2003, in which provinces in the north of the Netherlands cooperate with local businesses to realize sustainable energy projects.[36]

A project that went one step further in its ambition to use waste as a feedstock was an initiative by four food producers in Leeuwarden. They planned to set up a pilot plant based on waste from their industry. Like Groene Poort and BER, the project aimed to produce both ethanol and biogas (GAVE, 2005b). The expected capacity was 3000 hectolitres of ethanol and 100 000 m^3 biogas. If the pilot performed well, a full-scale installation would follow with 10-20 times more production capacity. A central partner in the project was the Energy Valley foundation (DN, 2005). In addition to Energy Valley and the food producing

[35] Like the Leeuwarden project below, the main collaborating partners in the Green Co. project was the Energy Valley, the Technologie Centrum Noord-Nederland, TNO, the Van Hall Institute supported the project. An additional partner was the German network called Niedersachsen Netzwerk Nachwachsende Rohstoffe Kompetenzzentrum from Werlte.

[36] One of the provinces participating is the Province of Friesland, known from the biodiesel experiments in the previous period. The aim of the foundation was to create regional growth and employment by starting a variety of sustainable energy projects. The ambition of Energy Valley was, and still is, to become one of the leading regions for the development and implementation of sustainable energy as well as knowledge and innovation in the field (Energy Valley, 2008).

companies, additional drivers of the project were the university, Noordelijke Hogeschool Leeuwarden, the research institutes TNO and Van Hall Instituut and a construction company with a focus on environmental technology, Oosterhof Holman Milieutechniek. Nedalco also participated. The Technologie Centrum Noord Nederland took on the coordination of the project and the plan was to build a plant by 2005 (DN, 2005). However, there has been no further news about this project, which makes it likely that it failed as well.

While high crop prices and competition with the food market seem to go hand in hand, yet another reason for the failure of ethanol production is mentioned in the case of Nedalco. Increased competition from imported feedstock or sugar cane ethanol is likely to have influenced the other ethanol producers as well. According to EVN (2005), Rotterdam harbour played and still plays a central role in supplying ethanol to the German, British and, especially, the Swedish markets. Companies in the harbour import ethanol mainly from Brazil. From 2001 to 2004 the import of ethanol through Rotterdam tripled from 200 000 tonnes to 600 000 tonnes. Rotterdam Harbour supplied half of all ethanol in Europe in 2004. Under the biofuel target of 5.75% by 2010 set by the Biofuel Directive, the estimated volume required in Europe was expected to be 10 million tonnes per year. The companies in Rotterdam Harbour expected to be able to deliver at least half of this future market. The largest players in this business were companies supplying fuel depots, such as Vopak (EVN, 2005).

In response to the increasing transfer of ethanol through Rotterdam Harbour, Vopak set out in 2005 to ensure that the storage and transport infrastructure at its terminal in Rotterdam met the strict ethanol storage and transportation regulations. The estimated ethanol storage capacity at Vopak was 150 000 m^3. This refers to ethanol from Brazil destined for Germany and Sweden. Its partners were the port of Rotterdam and the consultancy company in the field of energy and environment, Ecofys (GAVE, 2005m). In the same year, construction work began on the Vopak terminal in Rotterdam. Vopak announced the 'largest independent ethanol storage facility in the world' (Vopak, 2005). The expansion of the terminal continued and the company presented a plan to construct a dedicated ethanol terminal. In 2007, Vopak gained funds to aid the construction of the terminal from the EOS Unieke Kansen Regeling (UKR), a subsidy programme related to the Energy Transition policy of the Ministry of Economic Affairs. The reasons for funding this ethanol terminal were twofold. First, to contribute to national economic growth by improving the position of Rotterdam Harbour in the fuel sector. Second, to meet the increased demand for biofuels as a result of the new law that obliged biofuel distribution by oil companies from 2007, and thereby increase the opportunities for the Netherlands to reach its CO_2 reduction targets (SenterNovem, 2007a).

Other actors also made use of the strategic location of Rotterdam Harbour to take on new activities to provide for the growing European biofuel market. The chemical production company Lyondell Chemie Nederland B.V. was one of the companies inspired by the promises of a bio-based fuel market as a result of the Biofuel Directive. Lyondell saw opportunities for converting part of its production facility to MTBE, the fossil-based fuel additive, to produce the bio-based alternative ETBE. Lyondell's MTBE plant in Rotterdam harbour was the biggest in Europe at the time. To realize its plans, Lyondell sought cooperation with Rotterdam Harbour. In 2005, they decided to send a joint request for funding to the same UKR subsidy programme as Vopak. The application was successful and led to a grant of € 1.6 million at the end of 2005. The total budget for the project was € 4.2 million. After the award of the grant, Lyondell employed Ecofys to assist with project planning and reporting. At the time, Ecofys noticed an unexpectedly large growth in demand for ETBE, which led to a change to the original project plan in February 2007. The new plan switched to ETBE production straight away, rather than make a gradual transition from MTBE production to ETBE. Lyondell had the plant ready by late 2007. After a few months of operation, Lyondell concluded that the project was very successful. It delivered more CO_2 reductions than initially promised due to the decision to convert the whole plant to ETBE production. To feed the remaining MTBE market in the Netherlands, Lyondell had to import MTBE from other branches outside the Netherlands. The future goal was to increase the production of ETBE even more (Lyondell Chemie Nederland, Port of Rotterdam, & Ecofys Netherlands B.V., 2007). One reason why the project in the Netherlands went so well was probably Lyondell's long experience with ETBE production, which dated back to 1998 (GAVE, 2009e).

Many ethanol traders and producers followed in the footsteps of Vopak and Lyondell, inspired by the EU Biofuels Directive and the Dutch biofuel obligation that followed. In the case of Sabic Europe (Sabic, 2006), the conversion of their MTBE plant to ETBE was achieved in 2006, even before the Lyondell ETBE plant (Sabic, 2006). However, projects set up by fuel importers were also unsuccessful. One example is that of Harvest Biofuel B.V., which together with its English mother company Futura Petroleum Limited set out plans to build an ethanol plant with a heat and electricity cogeneration installation in the Amsterdam America harbour. Despite 10 years experience of ethanol production for the US market and a focus on the expanding export market, the plans to start production in late 2007 failed (GAVE, 2006a). The project was put on hold 'because of unfavourable market circumstances' (GAVE, 2009c, translation by the author).

	2003	2004	2005	2006	2007	2008	2009	2010
Ethanol (million litres)	–	–	–	38	176	218	284	278
Ethanol (% of total gasoline)	–	–	–	0.55	2.0	2.47	3.14	3.05
Biofuels, total (million litres)	4	4	3	67	463	449	586	399
Biofuels, total (% of total transport fuel)	0.03	0.03	0.02	0.38	2.78	2.56	3.42	2.09

Table 6: Consumption of ethanol and total biofuel in the Dutch transport sector, 2003-2010.

Source: Statistics Netherlands[37]

Table 6 indicates that the tax exemption in 2006 and the subsequent obligation from 2007 onwards had a great impact on the use of ethanol in this period. Ethanol use continued to increase in 2008 and 2009, but declined slightly in 2010. While high feedstock prices and criticism of the use of food crops may have slowed ethanol market penetration slightly, imports of cheaper ethanol are likely to have compensated for the fall back. The dip in 2010 is harder to explain from the experiments described. However, it is likely to relate to the reduced biofuel implementation target set out in EU and government policy at the end of this period, despite other small-scale stimulation measures in the form of TAB.

Biodiesel

The EU Biofuel Directive and a more encouraging national policy on conventional biodiesel inspired biodiesel actors in a similar way to the ethanol actors.

The central biodiesel cluster formed around pleasure boats and service boats continued throughout this period. The boat trial in Amsterdam continued, but the company Kooij and Plas, which began the biodiesel experiments on the Amsterdam waterbuses in 1996, split into two separate companies at the beginning of this period. This meant that Kooij

[37] Calculations regarding share of ethanol/biofuel based on total transport fuel energy base.

continued the biodiesel activities, which involved 16 waterbuses running on biodiesel, while Plas used fossil fuels only. The fuel importer Wiersma continued to provide the biodiesel (GAVE, 2009f).

The larger biodiesel boat cluster led by the Province of Friesland also continued its activities. The trial involved 14 inspection ships owned by the province, 21 pleasure boats from Holiday Boatin´, two agricultural vehicles at the agricultural company Gebranda state and last but not least the local Staatsbosbeheer had eight agricultural vehicles, two service vehicles and one excursion boat running on biodiesel. The aim of the Province was to increase biofuel use. The projected numbers aimed for were 225 pleasure boats, 10 agricultural companies and additional consumption of 25 000 litres of biofuel by alternative land and water managing organizations. Wiersma maintained a central position in the cluster (GAVE, 2009f; Van der Laak et al., 2007). The boating company Roukema, which was part of the network in the previous period and contributed to the start up of new experiments after 2002, was no longer in the network at the end of this period (GAVE, 2009f). There are no reports indicating that the number of biodiesel experiments expanded, which indicates that the province is not likely to have reached its goal of 225 boats and 10 agricultural vehicles. One potential reason for the withdrawal of Roukema was the ending of tax exemptions in January 2007. The initial tax exemption for the boating trial ran out in 2005, and the general biofuel tax exemption that came in thereafter was only valid for 2006.

Additional entrepreneurs planned to set up biodiesel projects in this period, but many stayed on paper or had severe start-up problems. The difficulty in starting projects can be exemplified by the transportation company Connexxion, which announced that a biodiesel bus trial would start in the city of Enschede in December 2005 (GAVE, 2005). Since the interest in greening the public transport sector was strong among local authorities, municipalities started to put pressure on Connexxion to use more environmentally friendly fuels, such as biodiesel, hydrogen and CNG, but nothing happened (De Gruijl, 2006). Once more Connexxion declared that a biodiesel bus trial would start – this time in the Province of Friesland in 2007. But this promise also failed to come to fruition (AGD, 2007). Eventually, in February 2008 Connexxion started to use biodiesel buses. The final goal was to run 27 buses. According to a statement by Connexxion, one reason for the delay was a conflict over whether to support conventional or more advanced biofuels. It decided to carry out the trial with conventional biofuels but prepare for better, more environmentally friendly, so-called second-generation biofuel options (LE, 2008).

One potential reason why the Connexxion trial succeeded at a later stage might be that the Province of Friesland had set high biofuel implementation goals, together with the other northern provinces, Drenthe, Groningen and Noord-Holland as part of the cooperation Energy Valley. According to Provincies Noord-Nederland (2008) they set out a vision in 2008 for realizing 100 000 renewable fuel vehicles by 2015. One motive behind this vision was that the obligatory biofuel implementation targets from 2007 had mainly contributed to low blend biofuel use while pure and high blend biofuels and other renewables were neglected (ibid.). Although the Frisian boating trial did not expand, the participation of the Province of Friesland in this Energy Valley-led vision may have contributed to the project continuing despite the end of tax exemptions in January 2007.

Another example of biodiesel trials carried out during this period is the main post delivery company in the Netherlands, TNT Post Group or TGP Post (currently Thomas Nationwide Transport (TNT) Post). Under the project name 'Driving Clean', TNT initiated a trial in 2006 with 56 delivery vans for a parcel service running on biodiesel in Amsterdam. The goal of TNT Post was to make its vehicle fleet more environmentally friendly. The company expected the package delivery vans to become greenhouse gas emission neutral and to improve air quality in the city by reducing small particulate emissions. The partners in the project were the municipality of Amsterdam, the vehicle supplier Pon VW, the lease company Athlon Car Lease and the biodiesel importer and distributor Wiersma, which also provided fuel for the boat trials in Amsterdam and Friesland (TNT Post, 2006).

According to the GAVE website (GAVE, 2009e), additional vehicle trials of biodiesel were carried out by fleets. One example is the municipality of Deventer, which started to run municipal vehicles on biodiesel in December 2007 after the municipality installed a local biodiesel refuelling pump. As a result, the local fire brigade and the municipal companies Sallcon and Circulus used biodiesel for their vehicles. Another example is the waste management company Area Reiniging, which started an experiment with waste trucks in November 2007. The biodiesel plant Sunoil in Emmen delivered the fuel (see below).

Early experiments with fleets had local biodiesel depots, but public biodiesel filling stations also started to appear in this period. Delta Oil was the first fuel distribution company to install a public biodiesel pump in 2005. It was set up at Delta Oils own refuelling station in Oostpoort industrial estate in Harlingen (GAVE, 2005n). According to data published on the website of Fuelswitch (Fuelswitch, 2010), a variety of distribution companies had expanded the number of pure (B100) and high blend (B30) biodiesel pumps to 15 in the Netherlands in June 2010. Counting biodiesel pumps just over the German border, 28 pumps were available for Dutch customers. According to SenterNovem (SenterNovem, 2010b), the subsidy programme for alternative fuel pumps (TAB) was not as beneficial for biodiesel as for other alternative fuels. The 2008 tender process did not include biodiesel, only ethanol and natural gas, but the 2009 tender process was restricted to support for the construction of B30 biodiesel pumps. In 2010, however, it became clear that only four pumps had been granted funding.

Experiments with biodiesel vehicles are quite limited compared to the great expansion of ethanol vehicles described above. This is rather surprising given that there is hardly any engine modification needed to drive on biodiesel compared to ethanol. The limited demand for biodiesel in the Netherlands may also explain why the biodiesel production plants set up in this period were aimed at the German market.

Although experimentation with biodiesel use started relatively early in comparison with other fuels, there had not been any production of biodiesel. Instead, projects used imported biodiesel. In this period, several entrepreneurs tried to start Dutch biodiesel production.

Piet van Ouden from the company Atep was one of the first to announce a plan for biodiesel production in the Netherlands. In mid-2003 an industrial estate at Kleefse Waard in Arnhem was bought from BASF Netherlands to serve as the location of the planned biodiesel plant. The biodiesel conversion process includes the separation of glycerine from the bio-oil using methanol. Most of the infrastructure for this process was available at the BASF plant. The German Company Olemühle Leer Connemann was to deliver additional technical equipment. Atep expected to invest tens of millions of euros in the plant. Atep planned to start production in 2004, based on an expectation that the government would grant a tax exemption that year. The biodiesel customers were companies with their own storage space for the fuel, such as the agricultural sector and various fleet owners. If Dutch demand was not large enough, Atep would sell biodiesel to the German market. The location of the plant, close to the river Rhine and Germany, was strategically chosen to enable export. According to Van den Ouden, the price of the biodiesel produced would be equal to, or even cheaper than, normal fossil diesel. He argued that only one unit of energy was needed to produce 2.5 units energy in biodiesel equivalence and that the use of a protein-rich by-product for animal fodder would lead to a total CO_2 reduction of 70 per cent for his biodiesel. Additionally, the emissions of soot and hydrocarbons would decrease (Voorter, 2003). Despite references to construction plans as late as 2005 (GAVE, 2005e), nothing came of them. I found no further information, indicating that Atep is no longer active in this field.

The second attempt to produce biodiesel started in 2004, when Hans de Haan the owner of Biovalue announced that he would set up two biodiesel factories, one in Dutch Eemshaven and one in Mecklenburg, Germany. Without subsidies, such as tax exemptions, he expected that the factories would return a future profit of 20 per cent despite his calculation that the biodiesel would be 10 euro cents more expensive than diesel. De Haan imported his biomass and saw the market for his biodiesel in Germany since, in contrast to the Netherlands, Germany had a tax exemption for biodiesel and high market demand (Van Wijland, 2004d). Expected production by the Dutch plant in the first five years was estimated at 85 million litres of biodiesel and as by-products 100 000 tonnes of rapeseed cookies for animal feed and 600 tonnes of artificial fertilizer (GAVE, 2009f). In mid-2005, De Haan announced that the financing, the rapeseed supply and biodiesel demand were in place for construction of the plant (GAVE, 2005c). However, when construction started one year later, it faced various problems and shortages of finances. Construction continued with financial support from the multi utility company Delta NV, owned by the province of Zeeland and its municipalities. Delta became a major shareholder (65%). Production started in August 2007. The plant had an oil press that could process 185 000 tonnes of rapeseed and an esterification unit that could produce 66 000 tonnes or 80 million litres of biodiesel. De Haan argued that his production process produced no waste and that it required lower chemical and energy inputs than conventional biodiesel production processes. This was partly due to the product, biodiesel, expected to reduce emissions, and the recycling of glycerine. Glycerine is a by-product of biodiesel production that has a limited market. Biovalue used it as an additive in the final biodiesel product. The glycerine additive is a patented process that Biovalue developed in collaboration with Groningen University. It increases the output of biodiesel and improves its characteristics. In vehicle trials carried out in Germany, biodiesel with the glycerine additive resulted in a fuel saving and a CO_2 emissions reduction. A more conventional way to make biodiesel production more cost-efficient and emission saving is to use the dry by-product rapeseed flour for animal feed or as a fuel for a combined heat and power plant (Arends, 2007).

Initially, the Biovalue plant seems to have been a success because Biovalue announced expansion plans the year it opened. A future goal was set to build additional plants to deliver 500 000 tonnes of biodiesel, and Biovalue was included in Energy Valley (Arends, 2007). The expansion plans are likely to have been a result of the Dutch obligation to distribute successively more biofuel. However, Biovalue was declared bankrupt in 2010. Biovalue's net profit had fallen from € 101 million in 2008 to € 7 million in 2009. The publicly owned subsidiary company Delta lost its investment of € 85 million in Biovalue (Schutte, 2010).

Sunoil Biodiesel also planned to build a biodiesel factory. Like Biovalue, it was interested in producing biodiesel for the German market, which was expected to have more stable demand. A contributory factor was that German investors supported the construction of the plant (Mudeva, 2005). Sunoil Biodiesel planned to have the plant ready for production by September 2005. The expected capacity was 35 million litres of biodiesel annually, but construction would provide space for double the expected capacity. The expectation was that the by-product glycerine could be sold to biogas installations for generating electricity or to the chemical industry (GAVE, 2005c). After some delay, construction of the plant started in October 2005 at a site in Emmen (GAVE, 2005o). In October 2006, Sunoil Biodiesel became the first factory to produce biodiesel in the Netherlands. The expected output of the factory rose to 80 million litres annually. The feedstock, bio-oil, came from the two Dutch oil mills North Netherlands Oil Mill and Twentsche Oliemolen, which processed rapeseed produced by Dutch farmers. The rest of the rapeseed oil was imported. In 2006, the main market for Sunoil Biodiesel was still in Germany, but there was a small Dutch market made up of Dutch oil distribution companies (DN, 2007). In 2007, the production process changed. Instead of focusing on PVO as feedstock, the plant started using waste oils, such as cooking oils and animal fats. In this way, Sunoil sought to avoid competition with food products and to increase the CO_2 reduction of its biodiesel to approximately 80%. In 2007, Sunoil reached the expected production capacity of 80 million litres of biodiesel. The final costs of the plant amounted to just over € 9 million. Part of the project had been to install a biodiesel pump in the city of Emmen to promote local companies' use of the fuel. In addition, Schiphol Airport started a trial with biodiesel in their service vehicles in collaboration with Sunoil Biodiesel. An additional plan was to stimulate further expansion of the pure biodiesel infrastructure, by installing B100 pumps across the Netherlands. Like Biovalue, Sunoil was eager to improve the environmental properties of its biodiesel by using the by-product glycerine as an additive in its biodiesel (GAVE, 2009e).

Sunoil Biodiesel was not alone in the field of biodiesel production from waste fats and oils. The technology was known in Germany and a Dutch company, Vierhouten Vet, which used cooking fat, started supplying waste fat to German biodiesel producers in 2004. However, in 2006 Vierhouten Vet decided to produce biodiesel from the waste oils directly. Vierhouten explained its decision by referring to the biofuel distribution obligation and the limited biodiesel production in the Netherlands (Koopman, 2006). In January 2007, the factory started producing biodiesel under the name Vierhouten Vet & Biodiesel Kampen (De Goeij, 2007).

The production of biodiesel from animal fat was also expanding. In 2005, Rendac, a company processing butchery and animal waste products, announced that it would set up a test factory for biodiesel production from animal waste fats in Son in the Province of Noord-Brabant. The test factory was expected to produce 2.2 million litres of biodiesel annually. Rendac planned to run its fleet of 150 trucks on the fuel. However, Rendac needed tax exemptions for a commercially viable business, and hoped for a subsidy that would support the construction costs of the biodiesel processing factory. Rendac estimated the construction costs at € 3–4 million. If the trial was successful, Rendac would scale up the factory (LC, 2005). Despite the lack of a long-term tax exemption from the government, interest in the proposition grew at Rendac's subsidiary food company Vion. Eventually, Sobel, a division of Vion, took over the project and gave it a new name – Ecoson. The new owners increased the expected output to 5 million litres annually and secured funds for the construction of the factory. According to the director of Sobel, Sjors Beerendonk, the funds came as a result of increased EU pressure to produce local biofuels, which created more belief in the company. Moreover, while vegetable oil was scarce in the Netherlands, animal fats were plentiful and locally available (Engwerda, 2007). The Ecoson factory was completed in December 2007. It is a production facility for both biodiesel and bio energy. Annual production capacity was 8 000 MWh of electricity and 9 000 MWh of thermal energy from biogas, 50 000 tonnes of refined fat and 5000 tonnes of biodiesel. By these means, Ecoson estimated savings of 4600 tonnes of CO_2 emissions annually. Rendac expected to start a trial using biodiesel in its vehicle fleet in 2007 (Vion, 2007). According to the GAVE website (GAVE, 2012), the Ecoson factory was still running in 2012, producing fat for the energy industry, biogas and biodiesel. However, Rendac had not started its biodiesel vehicle trial in 2012.

However, there were also less successful initiatives in the field of waste fats and oil biodiesel. One of them was the initiative of Ten Kate, which announced that the production of animal fat biodiesel would start in June 2006 (DN, 2006). After the announcement, there was no other media coverage related to this project. However, a new announcement appeared on Ten Kate's website in 2010 (Ten Kate, 2010). Since 2009 Ten Kate has produced lard oil that can be used for various purposes, including biodiesel production (ibid.). However, there has been no further reporting on biodiesel partners, plans or practices. Hence, we may conclude that Ten Kate has not yet been able to achieve biodiesel production.

Competition with food products might have contributed to the fall in rapeseed production plants, but both rapeseed and waste biodiesel producers faced the threat of cheap imports of biodiesel at the end of this period. In early 2007, biodiesel production by Vierhouten Vet and Sunoil Biodiesel faced competition from cheap, subsidised US biodiesel which entered the European market through Rotterdam harbour. The rapid loss of customers on the Dutch market meant that Vierhouten Vet had to end its biodiesel production. The directors of Vierhouten Vet, Biodiesel Kampen and Sunoil Biodiesel, sent a joint letter to the Dutch Parliament appealing for help. Other biodiesel companies at the European level shared their concern, which led to action at the EU level by the European Biodiesel Board (EBB) (De Goeij, 2007). At the national level, Dutch biodiesel producers formed a Dutch Biodiesel Association, Vereniging Nederlandse Biodiesel Industrie (VNBI), in late 2007 to prevent unfair competition from imported biodiesel. In this network, the established companies Biovalue, Vierhouten Vet & Biodiesel Kampen and Sunoil Biodiesel joined forces with new biodiesel companies emerging in 2007. The new companies were Biopetrol Rotterdam, Clean Energy, Dutch Biodiesel, J & S Bioenergy and Rosendaal Energy. The intention was to make the Netherlands into the largest biodiesel producer in Europe within two years. The capacity of the Dutch biodiesel sector in November 2007 was 1.5 million tonnes, which equalled the target for 10% substitution of Dutch diesel consumption outlined in the EU and Dutch biofuel policies. The association stressed the ability of biodiesel to reduce CO_2 emissions and substitute for fossil fuels (Energieraad, 2007). The fact that biodiesel was only one of many products Ecoson produced could explain why the Ecoson factory was not part of this initiative.

	2003	2004	2005	2006*	2007*	2008	2009	2010
Biodiesel blends (million litres)	0	0	0	26	283	231	301	121
Biodiesel and PVO pure (million litres)	4	4	3	3	3	0	0	-
Biodiesel (% of total diesel)	0.05	0.05	0.04	0.35	3.28	2.61	3.66	1.44
Biofuels, total (million litres)	4	4	3	67	463	449	586	399
Biofuels, total (%of total transport fuel)	0.03	0.03	0.02	0.38	2.78	2.56	3.42	2.09

Table 7: Consumption of biodiesel, PVO and total biofuel in the Dutch transport sector, 2003-2010.

Source: Statistics Netherlands[38]

*The division between pure and blended biodiesel in these years is approximate.

Table 7 indicates that before 2006, all biodiesel consumption was pure fuel (B100). Total biodiesel consumption increased greatly because of the government tax exemption granted in 2006 and the obligation to distribute biofuels from 2007, with increasing targets over the years.

[38] Calculations of share biodiesel/PVO and total biofuel used is based on the transportfuel energy base.

Obligatory biofuel distribution allowed for certain flexibility over the years and between different biofuels. According to the statistics, the lion's share of biofuel distributed was in the form of low blends in biodiesel. By 2008, the use of pure biodiesel (B100) and PVO was so small that it no longer showed up in the statistics. The increase in distribution locations providing B30 shows that the high blend niche was increasingly replacing the previous interest in pure use.

While 2007 showed an explosion in biodiesel use, 2008 and 2010 show severe dips. This in turn affected total biofuel consumption (see Table 7). While the policy on biofuel implementation targets allowed for flexibility over the years, this dramatic change in consumption is likely to have happened for a reason. The problems of producing sufficient biodiesel could explain the reduction. Actors in the above-mentioned initiatives lacked funds and increasing feedstock prices as a result of competition with foods caused failures in domestic production. However, with time, imports or the increasing trend for using waste as a feedstock are likely to have compensated for the greater part of these shortfalls. Another potential contributory factor to the declining use in 2010 was the reduction in obligatory implementation targets in 2009. Moreover, in 2009 the government introduced a regulation on the 'Double counting of biofuels', which meant that actors did not need to distribute such a large amount to reach the biofuel implementation quota. According to Segers (2011), fuel distributors used this double counting measure extensively. Hence, fuel distributors distributed waste oils that counted double due to their particularly good environmental benefits, which meant that the total amount of biodiesel distributed declined.

PVO

PVO did not expand as much as the use of ethanol and biodiesel in this period. A contributory factor was the biofuel distribution obligation, which led to the easy and low cost implementation of biofuels as low blends in fossil fuel, a practice that was only possible with ethanol and biodiesel.

That PVO was included under pure biodiesel in the statistics of Statistics Netherlands presented in the Table 7 indicates the small size of this niche. However, despite its marginal size, the market niche expanded and reached its peak in this period. After 2008, PVO and pure biodiesel use was more or less non-existent (see Table 7).

A facilitator for the initial growth of the PVO niche was the eight-year tax exemption for the use of 3.5 million litres of PVO gained by the Abersons and NLTO in 2002. This grant contributed to the setting up of the first rapeseed oil mill. Domestic PVO production, not imports, was the route by which PVO entrepreneurs expanded the PVO vehicle niche in this period.

Setting up the first oil mill was not a straightforward process. After preparations in the early 2000s, the PVO actors decided to construct the mill at the port city of Delftzijl close to the German border to facilitate future import of raw material and export of PVO. At the same time, financing for the oil mill started to materialize. The network managed to overcome the first bottleneck when Rabobank agreed to cover the initial investment or deposit that the farmers had to pay to qualify for the European Commission subsidy for non-food cultivation (Bijlsma, 2003f). A second breakthrough occurred in August 2003, when the Abersons' succeeded in enrolling 150 farmers in the project. The farmers agreed to contribute rapeseed feedstock and to become shareholders in the oil mill, thereby financing the mill. This meant that the farmers would deliver 750 hectares of rapeseed (Bijlsma, 2003b) and invest € 250 per hectare. The network expected to recover its investment in 10 years (Bijlsma, 2003g). There was an official announcement that the construction of the mill would start (FD, 2003), but investment was not sufficient. Unfortunately, before the last financial agreements were made, the EU Council of Ministers of Finance decided that PVO, if used as a fuel, should fall under the definition of mineral oil and not biofuel. This meant that the PVO market would have difficulties expanding and competing with biofuel alternatives because new PVO initiatives would not gain the general tax exemption promised by the government. Only the PVO initiatives that already had a tax exemption, such as the one gained by the Abersons in 2002, would enjoy continued support until the exemption ended in 2010 (Bijlsma, 2003d). The North Netherlands Oil Mill was one of the few with such a long-term tax exemption. Most biofuels would only enjoy the one-year tax exemption given by the government in 2006. The tax exemption given to selected PVO projects also meant that they would not be accounted for in the biofuel obligation introduced in 2007. Only biofuels with no tax exemption would contribute to the obligation (Staatsblad, 2006).

Despite the barriers set up by the change in EU policy, the North Netherlands Oil Mill project managed to gain sufficient financing. By the end of 2003, farmers had signed up for € 80 000 in stocks and the NLTO invested € 100 000 (Bijlsma, 2004). Additional investments came from the Ministry of Agriculture, Nature and Food Quality (LVN), the Province of Groningen, the German farmer cooperative, Grenzland, and the road constructor Smid and Hollander (Bijlsma, 2003c; Bijlsma, 2004). In February 2005, the network announced that the oil mill would open in two weeks. However, the opening was delayed due to problems with environmental licences and safety standards (GAVE, 2005b). Eventually, in July 2005 the Minister of Agriculture officially opened the oil mill – the first oil mill in the Netherlands (GAVE, 2005j). Since there was no Dutch standard, the mill adopted the German PVO standard to ensure the quality of the fuel produced (GAVE, 2012). The mill processed about 7500 tonnes of rapeseed annually. While the majority of the production was PVO for vehicles, the plant saw opportunities in other markets such as cooking oil and raw materials for soap and ecological herbicides. Market expansion was part of the initiative by De Uitbreiding, which was set up in collaboration with the University of Groningen. In addition, the mill sold part of the PVO produced for biodiesel production. As is outlined in the biodiesel sub section above, the Sunoil biodiesel plant used pure oil from the mill as a feedstock in 2006-2007 before it decided to use waste oils instead. However, according to the project description on the GAVE website (GAVE, 2012), the production at the mill was put on hold in early 2009 due to 'unfavourable market conditions'. According to Aberson (Aberson, 2011), the termination of the tax exemption in 2010 led to even more unfavourable market conditions for PVO, despite the fact that it could profit from the biofuel obligation. In Hein Aberson's own words it was 'the end of the PVO fuel market' (ibid., translation by the author).

Another oil mill project was set up by Organisatie voor Plantenolie en Ecologische Krachtbronnen (OPEK) Nederland, an organization for producing plant oils from ecological energy sources founded in 2003 (Van der Laak et al., 2007). The aims of the OPEK entrepreneurs, Pieter Huib Klomp and Gilbert Veldhuizen, were to stimulate local production and use of PVO and the construction of an oil mill. Like the Abersons, the OPEK entrepreneurs gained inspiration from Germany – a forerunner in PVO technology (Didde, 2002). They gained an eight-year tax exemption based on the decision of the Ministry of Finance in 2002 to support selected biodiesel and PVO projects. The exemption for Klomp and Veldhuizen, however, was much lower than that for the Abersons, covering the use of 500 000 litres of PVO annually. By late 2004, the oil mill located in Zeewolde was ready to start production. Their plan to use local feedstock and produce oil for the local community, however, did not work out. Local farmers were not willing to swap over to rapeseed cropping. Sugar beet was the crop they cultivated and sugar beet gave the farmers more profit. The tax exemption, rising diesel prices and the possibility of importing rapeseed from other European countries meant the OPEK oil mill managed to start production. By converting and driving

OPEK's own trucks on PVO, OPEK was able to take a profit from the project due to the relatively low price of PVO compared to fossil diesel (Rennen, 2005). They converted two trucks and like Solar Oil Systems they also assisted the conversion of diesel engines to PVO engines. In addition to its activities in the Netherlands, run under the project name Ketenproject raapzaadolie (KEPRO), OPEK runs a project in Uganda to stimulate local PVO production (GAVE, 2009b). More recently, however, OPEK has reduced its production of PVO to adjust to 'market conditions' (GAVE, 2012). This development may, as in the case of the North Netherlands Oil Mill, be related to the ending of the tax exemption.

Fokkink and his company Biofuels, in Neede, initiated a third PVO production project. The company cultivated rapeseed, sold rapeseed presses and various kinds of oils (rapeseed and linseed) and modified car engines to run on PPO. Since 2003, the company has been the Benelux dealer for an oil press built by the Swedish company Skeppsta Maskin AB, also known as Täby Pressen. In 2004 Fokkink sold 2500 litres of PVO and converted two cars to run on plant oil (GAVE, 2009a). According to Van der Laak (2005), the oil produced by Fokkink was only sold to food processing companies. This was linked to the fact that Fokkink did not receive a tax exemption like Abersons and OPEK. Apart from some sporadic contacts with Hogeschool Enschede, there were no further actors involved in Fokkink's project. According to the homepage of Biofuels B.V. (2008), no sales of PVO were reported, but both the conversion of vehicles to PVO propulsion and the delivery of small-scale oil presses were still part of Fokkink's business activities in 2012.

Unlike the activities of Fokkink and OPEK, the PVO network around the Abersons was eager to share its experience, contribute to the expansion of PVO production and share their knowledge related to the North Netherlands oil mill. The municipality of Venlo cooperated closely with the Abersons and was one of the first actors to implement PVO. It was also a great advocate of PVO and contributed to the setting up of a second PVO cluster in the Province of Limburg. The Dutch Carnola Cooperation initiated this PVO cluster. It is an organization of rapeseed cultivators in the Province of Limburg and Vereniging Innovatief Platteland Venray (Innovative Rural Venray). Venlo contributed to this cluster by reaching an agreement with the Dutch Carnola Cooperation. This agreement meant that Venlo would make use of the oil mill when it started producing PVO in 2005 (GAVE, 2009f). Venlo's decision to support the construction of the southern PVO cluster was not in conflict with its PVO activities in the north because the North Netherlands Oil Mill had already negotiated a division of the PVO market with the Carnola Cooperation. The North Netherlands Oil Mill had agreed to serve all customers north of the city of Utrecht, while the Carnola Cooperation would serve customers to the south (Solar Oil Systems, personal communication, 18.06.2007). The rapeseed farmers who were part of the Cooperation had started to cultivate rapeseed in 2003. Until the oil press was ready, a German company pressed the seed to PVO. In 2005, the Dutch company Gebr. de Boer Loonbedrijf in Lottum took over the production of PVO for the Carnola cluster. Eventually, three funds made the construction of the oil mill possible. First, the EU gave a subsidy of € 43.000. Second, the government gave additional support in August 2005 in the form of a tax exemption. The exemption covered the production of 3 million litres of rapeseed oil or approximately 2000 ha of rapeseed annually, the continuation of which the government would evaluate on an annual basis. In this way, the Carnola Cooperation gained a third tax exemption for PVO, despite the previous announcement that no additional tax exemptions could be granted due to new EU agreements (GAVE, 2005a). After some negotiation, the EU officially granted this particular PVO tax exemption to the Carnola Cooperation for the period 2005-2010 (EC, 2007c). Third and finally, additional funds came from the Province of Limburg which supported the customers of the Carnola Cooperation (GAVE, 2005a). As part of the Provincial project, Koolzaad op de weg, PVO vehicles and pumps were subsidized, which facilitated the creation of a market for the oil mill (GAVE, 2005r). In 2005, the Carnola chairman, Joop Hermans, stated that the project was popular and customers were standing in line (GAVE, 2005a). In the first year, 2005, Carnola sold 300 000 litres of PVO. In 2007 a peak of 1.4 million litres was reached, but in 2008 production returned to the level of the first year. According to the Carnola Cooperation, the steep decline in production was due to increasing food prices and thus also the price of the feedstock for PVO (Bouten, 2009). Like the North Netherlands Oil Mill, the Carnola Cooperation was producing oil for both fuel and food products. The government tax exemption was ended in January 2011 (GAVE, 2012). The PVO market is likely to have suffered despite the fact that it could benefit from the biofuel obligation like all other biofuels. Joep Hermans at Carnola remained positive and saw the potential for a continued PVO tax exemption despite rejection at the EU level. His argument was that Carnola had only produced 4 million litres of rapeseed out of the tax exemption granted for 15 million litres, and that the Ministry of Finance was positive. The extent to which the lack of a tax exemption will affect PVO production at Carnola is as yet unclear. Recent investment in other markets, such as trade in wheat, indicates that it is preparing for the worst (Engwerda, 2011).

In addition to the oil mill initiatives in Friesland (the North Netherlands Oil Mill) and Limburg (Cooperation Carnola), Aberson has advised and supervised the construction of other cold press oil mills in the Netherlands. There were oil mills in the Provinces of Drenthe, Noord-Holland, Zeeland, Flevoland, Overijssel and a second oil mill in Friesland. The Abersons have also given advice to projects abroad, for instance in Belgium, Canada and Poland (GAVE, 2009f). However, there is very limited information available on many of the projects that started after 2005. One possible explanation for this is that these projects either never started or did not survive. Two projects made it quite far. The first was a project in Overijssel that was stimulated by the Abersons' North Netherlands Oil Mill, and the second is a parallel project in Gelderland that was developed in collaboration with Fokkink.

Johan Vogt and Frank Slijkhuis from Hengevelde in Twente, part of the Province of Overijssel, started preparations for an oil mill in late 2005. Inspired by the activities of the Abersons, they wished to attract local farmers with rapeseed to the project. The farmer cooperative ABCTA (currently known as ForFarmers), which traded in animal fodder, became a partner. The granting of a tax exemption for PVO was a necessary precondition to realizing the project (AGD, 2005), which made the Twentsche Oil Mill one of the most eager lobbyists for a tax exemption (Boerderij, 2006).

In parallel with the development of the Twentsche Oil Mill, farmer Roland Kleine from Almen, a village in the Province of Gelderland, started a small-scale experiment with an oil press in 2005. Fokkink delivered the small-scale oil press that Kleine had been experimenting with. The success of this experiment led to ambitions for large-scale production and the formation of the company Achterhoekse Oliemolen B.V., together with two partners of which one was Joost Fokkink. The project counted on the granting of a general biofuel tax exemption in 2006 (Vink, 2005).

However, as is mentioned above, the general tax exemption did not include PVO. With time it also became clear that the exemption was not long term, but only a one-year exemption for 2006. To facilitate political activities, such as lobbying for tax exemptions, and carrying out research into making the processing of rapeseed and its products more efficient, farmer organizations (LTO Noord, ForFarmers) and individual farmers decided to set up a rapeseed association, which eventually 65 individual farmers joined. However, the Ministry of Finance rejected its request for tax exemptions (Boerderij, 2006).

Despite the lack of tax exemptions, the Twentsche oil mill started to produce rapeseed oil in May 2006. The capacity of the mill was 8000 tonnes of rapeseed annually, which is equivalent to the production of three million litres of oil. The oil mill served both the biofuel and the food market. The absence of a tax exemption meant that it sold part of its rapeseed oil on the German market (Tonjes, 2006). One of the main reasons for its success was a contract signed between the Twentsche Oil Mill and the For Farmers cooperative, which represented the majority of the farmers in the region (Hofman, 2006). However, in 2007 business slowed and in the summer of 2008 the Twentsche Oil Mill was forced to close. There had not been a sufficient financial return because the availability of local feedstock set limits on production capacity. Local rapeseed cultivation had not expanded as expected due to sudden price increases of 30-40 per cent on local agricultural land. Moreover, importing feedstock was not a competitive alternative due to the location of the company. In this context, the lack of a government tax exemption weakened its financial situation (Tubantia, 2008). In conclusion, dependence on local feedstock and the lack of a tax exemption made the Twentsche oil mill less able to cope with the fluctuating feedstock prices that led to its downfall.

Business did not go that well for Kleine and the Achterhoekse Oil Mill, either. Kleine failed to attract partners and withdrew his plan to start large-scale PVO production in 2006. However, he continued to produce small amounts of PVO based on the rapeseed that he cultivated himself (Vink, 2006; GAVE, 2009f). The lack of a tax exemption was the main reason for the failure of the Achterhoekse Oil Mill. In addition, the fact that Kleine was located in the same region as the Twentsche oil mill and that the Twentsche Oil Mill had managed to attract the bulk of the farmers in the region is a likely explanation for why Kleine failed to scale-up his project.

Pressing seeds is not the only way to produce PVO. There were also several initiatives that used waste oils or fats – a trend which was also visible in the biodiesel case. PPO Groeneveld, a company set up in 2002 by Ger Groeneveld, started to recycle oils used in the food industry in order to process them into a quality PVO. Groeneveld had been experimenting with the conversion of waste streams to fuel since 1998 (Groeneveld, 2005). He produced 50 000 litres annually. Farmers bought Groeneveld's fuel to use in agricultural vehicles. Groeneveld gained financial support from the Province of Friesland through the Actieprogramma Duurzaam Ondernemen (the Action Program for Sustainable Entrepreneurs). The project ran under the name Sonnebrand Fryslan (GAVE, 2009f). According to reports on Groeneveld's activities, in recent years (see: Gota Verde, 2010), more attention has gone into the production of PVO in developing countries and the production of PVO from waste oils in the Netherlands seems to have ended.

Another company in a similar business was Polskamp Meat Industries (Polskamp Vleesverwerkende Industrie), which produced PVO from recycled chicken fat that was fed into a company truck. Unlike Groeneveld, Polskamp used the PVO for its own purposes only. Polskamp saw greater potential in using chicken fat in the bioenergy sector, arguing that he might expand the PVO project if suitable subsidies were available (GAVE, 2009f). However, engine problems occurred after only one year and Polskamp decided to end the trial. The engine problem was due to the high water content in the chicken fat fuel (Change, 2008). The use of waste food and oils for PVO was not as successful as initially expected. As is noted above, waste feedstock is more suitable for biodiesel production.

There were also various activities promoting the use of PVO. Here also, the Abersons were one of the central players starting up or inspiring others to start projects. One of the reasons behind the stimulation of PVO projects was the Abersons' own business, Solar Oil Systems, which had been adapting diesel vehicles to PVO since early 2003 (Bijlsma, 2003e), and their need to find clients for the North Netherlands oil mill and arrange the related fuel distribution (FD, 2003).

As is reported above, the Abersons' first customer was the municipality of Venlo. In 2002, Solar Oil Systems converted one of Venlo's street sweepers to run on PVO. The experiment with the street sweeper was successful and the municipality decided to expand it (GAVE, 2003d). As a result, there were three street sweepers in Venlo by 2009. If these sweeping cars ran well the municipality planned to convert the last three street sweeping cars and additional service vehicles in their fleet. Before PVO was available in the Netherlands, these street sweeping cars ran on imported PVO from Germany (GAVE, 2009d). To date (April 2012) there is no indication that additional vehicles have been converted. Venlo has also vanished from the list of biofuel projects on the GAVE website (GAVE, 2012). Given that the Carnola PVO plant was distributing the fuel to Venlo from 2005, and that the plant is still running, there is a chance the project is still running.

Additional trials started in connection with the Carnola plant, which in turn was a spin-off from Abersons' PVO projects, as is outlined above. Carnola's distribution of PVO was restricted by law to vehicle fleets (Heesen, 2011). One of the first large customers of the plant was the farmers' cooperative SaWeCo, which provided rapeseed to the plant. SaWeCow had converted one of its trucks to run on PVO, which consumed about 30 000 litres of PVO per year (GAVE, 2005a). There is no more information on the web about this project.

However, this and additional PVO fleets are likely to have been stimulated by local support measures set up by the project Koolzaad op de weg, driven by the province of Limburg in collaboration with the Carnola mill in the South of the Netherlands. Examples of local subsidies were a 30 per cent price cut for converting a car engine to run on PVO. Duurzame Energie Fonds Limburg (the Sustainable Energy Fund Limburg) also gave an up to 30 per cent subsidy for the construction of PVO pumps (GAVE, 2005r). While the local subsidies are likely to have contributed to additional experiments, Joep Hermans, chairman of Carnola, argued that the tax exemption was the main driver of market expansion in the southern PVO vehicle market. Additional trials with sweeping cars in Maastricht and the heavy vehicles of the animal the feed company, Vitelia, and the transport company, Van Leendert, are some examples triggered by the lower fuel price which PVO use implied. However, in 2008 diesel became cheaper while PVO became more expensive due to higher food prices. This led to a collapse of the PVO vehicle market. Once the Carnola tax exemptions ran out in 2011, the situation became even worse (Heesen, 2011).

Meanwhile the experiments were expanding even more in the north or the country. Solar Oil Systems facilitated the implementation of additional sweeping cars at the large indoor Flower Auction in Aalsmeer. Solar Oil Systems provided the technology to convert the sweeping vehicles of Hago, the cleaning company at the Flower Auction. They also provided the PVO fuel. The experiment started in September 2004 with one street sweeping car. To prevent the deep fried smell, the Flower Auction invested in a filter. The plan was to broaden activities to cover all five street sweeping vehicles (GAVE, 2009f), but the expansion plan was not implemented and the Flower Auction terminated the project in 2007 (GAVE, 2009e). The halt in production at the North Netherlands Oil Mill is likely to be the reason for the termination.

In addition to sweeping vehicles, there were experiments with trucks. McDonalds was one of the first large customers of the Abersons (Bijlsma, 2004). Initial preparations began in 2001. There had been a request from McDonalds to drive their waste trucks from the Dutch waste processor Sita on McDonalds' own recycled kitchen oil. However, current fuel standards prevented the use of recycled kitchen oil. Hence, the project partners decided to use PVO. After negotiations with Sita and a local Mercedes dealer, the Abersons decided to convert the McDonalds trucks (Van der Laak, 2005). The first truck was on the road in October 2003 (GAVE, 2003f). Eventually, two additional trucks were converted to run on PVO (GAVE, 2009f). According to reports, the waste trucks ran satisfactory from day one (GAVE, 2008). However, since early 2010 the number of trucks running on PVO has reduced (GAVE, 2012). The reasons why were not reported, but are likely to be related to the halt in production at the North Netherlands Oil Mill.

After the positive experiences with the trucks at McDonalds, Sita decided to convert additional and heavier 'ecocombi' trucks to run on PVO. Despite support from the Ministry of Transport, Public Works and Water Management, which promoted these vehicles publicly in 2004, and an implementation date in 2006 (GAVE, 2005v), the trial was never mentioned again. The lack of information or reports on the trial indicates that the project never started.

Sita was not alone. The Municipalities in the region of Zeeuws-Vlaanderen were also unsuccessful in their attempts to implement PVO in their service vehicles. Initially, they were very enthusiastic (GAVE, 2004j), but three months later the plan was withdrawn. One of the major reasons was that correct information about the costs had not been available when the initiative was presented (Van Wijland, 2004c; GAVE, 2004h).

However, despite a few failures to initiate trials, interest grew in experimenting with waste collection trucks. Omrin, a waste management company in the north of the Netherlands, started one of the initiatives. The city of Leeuwarden became Omrin's partner with the idea that using PVO would reduce the city's CO_2 emissions (GAVE, 2005f). In the autumn of 2004, Omrin initiated its first project with PVO propelled street sweeping cars in Leeuwarden. In March 2005, Omrin initiated a second project with two waste collection trucks running on PVO in the municipality of Achtkarspelen. Together, these two projects consumed about 600 litres of PVO per week. Crucial partners for Omrin were Abersons' Solar Oil Systems and the car company Autobedrijf ESA, which facilitated both projects. In May 2005, Omrin announced that an additional four waste collecting vehicles running on PVO would be introduced in the Province of Groningen (GAVE, 2005k). The expansion plans were successful and by 2007 Omrin was running 25 PVO vehicles (Gemeente Leeuwarden, 2007). As of April 2012, Omrin's homepage still reported the use of PVO in 20 of its vehicles. However, green gas is seen as the future fuel and there are plans to convert up to 130 vehicles to gas propulsion (Omrin, 2012).

Various actors showed an interest in PVO bus trials. In 2005, the BBA, the bus company in the Province North-Brabant at the time, started a trial with two local buses. This was first trial of PVO in buses in the Netherlands. Instead of using pure PVO, these were hybrid buses running on either PVO or diesel. Solar Oil Systems and the car company EMA Autobedrijven B.V. were involved in setting up the project. The hybrid buses were fitted with two fuel tanks, one for PVO and the other for diesel. Hybrid buses were chosen to resolve the known cold start problems when using PVO. The bus driver could start driving on diesel and switch to PVO once the engine had warmed up. To facilitate the use of PVO, the bus company arranged for a local depot in Reusel to store the fuel, which came from the North Netherlands Oil mill. The tax exemption given to the North Netherlands Oil Mill meant that the fuel was about € 10-15 cents cheaper. Due to the temporary nature of the exemption, lower fuel costs was not the official reason for the trial. According to the manager of BBA, this was to evaluate the possibility of driving buses on environmentally friendly fuel (GAVE, 2005q; GAVE, 2009f). Partly stimulated by the trial, local authorities in Reusel de Mierden leased 8-12 hectares of leasehold land for rapeseed cultivation (GAVE, 2009f). However, this may also have been stimulated by the lobbying for rapeseed cultivation that took place before and during the trial (GAVE, 2005p). According to GAVE, the bus trial was still running in 2007 (GAVE, 2007b). However, there has been no recent reporting on the BBA trial, and it is likely that it was also decided to terminate this trial.

In addition to street sweepers, trucks and buses, various cars have also been running on PVO. In January 2006, the Municipality of Noord-Beverland had its first van running on PVO (Tamatgreen, 2006). Two of the nine delivery vans of the municipality later ran on PVO. The company Tamatgreen VOF converted the engines using Elsbett technology. The high viscosity of PVO has resulted in the well-known problem of clogged engine filters, particularly when using the fuel in the winter. In addition to the PVO trial, the municipality planned to run the vans they have left on a mix of biodiesel and normal diesel (GAVE, 2009f). The decision to use a blend with diesel is likely to be related to the clogging problem. The inability to find further information on this trial leads to the conclusion that it has now ceased.

In 2007, a collaboration of various private, non-profit and religious organizations set up the project Rijschoon.nu (Drive Clean Now) in cooperation with the Province of Noord-Holland. Funding for the Province granted by the EU regional development programme 'Leader +' was decisive in realizing the project (Rijschoon, 2009). The goal was initially to introduce as many as 50 PVO cars by the end of 2007 (GAVE, 2008). By 2009, however, only 14 PVO cars were running as part of the project. The reason for introducing vehicles using alternative fuels was to substitute for fossil oil. The motto of Rijschoon.nu was 'not to wait but to act with the available means'. The intention was to broaden the trial to other fuels such as ethanol and biogas (Rijschoon, 2009). The non-availability of any information and the shutting down of the project website indicate that this project was also short-lived.

The company Verkeersschool Nijland introduced PVO in cars used for driving lessons. This project was also supported by Solar Oil Systems (GAVE, 2009f). Currently, there is no information about PVO vehicles on the website (Nijland, 2012), which indicates that the trial is likely to have ceased once production at the North Netherlands oil mill was halted.

As is shown above, the majority of PVO experiments that emerged during this period were either collaborations with the Abersons or spin-offs from their activities. In addition to aiding and stimulating PVO trials with actors in the field, the GAVE newsletter (GAVE, 2009f) reports that Solar Oil Systems collaborated with automobile interest groups such as ANWB and VW/PON, the importer of Volkswagen. Solar Oil Systems has also given advice on a range of PVO applications, such as various types of vehicles, boats and boilers (GAVE, 2009f). However, many of the projects ended around 2008 and 2009, which coincided with increasing PVO prices and the halt of production at the North Netherlands Oil Mill. Some trials dependent on other oil mills, such as the Carnola Cooperation, seem to still be operating.

Distribution activities also took place. The main mills, the North Netherlands Oil Mill and Cooperation Carnola, were more or less forced to distribute their fuel to fleets, which meant that no public filling stations were built. Another reason why public refuelling stations did not develop that rapidly, while the use of PVO increased, was the availability of vegetable oil over the border in Germany or in local supermarkets. According to Hogeschool Hanze (2010), it is prohibited to use cooking oil in vehicles in the Netherlands, since the cooking oil attracts no fuel tax, but many hobbyists make use of it. According to Bijlsma (2002b), the Abersons used cooking oil in their first vehicle experiments.

The Abersons made one of the first attempts to set up a public PVO refuelling station. In addition to the private pump at the Solar Oil Systems garage for converting diesel vehicles to PVO propulsion, the Abersons tried to set up a public PVO filling station at the industrial park De Oevers in Meppel (Bijlsma, 2003e). However, the filling station did not receive permission to start operating. Due to the lack of regulation with regard to PVO as a vehicle fuel, the government did not grant the necessary permit for storing PVO (Bijlsma, 2003a). Instead, the first filling station was built by Delta Oil in Drachten in 2005 (GAVE, 2005n). The fuel was partly taken from Delta Oils oil mills in Leeuwarden and Harlingen (GAVE, 2009f). Since January 2006, an additional distributor, New Energy, has sold PVO in Amsterdam. The PVO came from the oil mill set up by OPEC. Ministry of Housing, Spatial Planning and the Environment, the Province of Noord-Holland and the city of Amsterdam are some of the actors that contributed financially to the establishment of the fuel station (NEWNRG, 2010). According to the Hogeschool Hanze (2010), eight additional filling points for PVO have been set up in addition to those of Delta Oil and New Energy in recent years, as well as a system that enables customers buying vegetable oil in supermarkets to pay fuel taxes in order to legally make the use of the oil in their vehicles. However, unlike the PVO delivered by oil mills and fuel stations, the oil sold in supermarkets does not conform to the German PVO fuel norm (DIN 51900), which means that use of supermarket oil has fewer guarantees with regard to negative effects on the engine (ibid.). Today, there is hardly any information available on the location of PVO distribution points. A biofuel information website [39] maps many PVO distribution locations, but many links to their websites, such as that of NEWNRG, are no longer working. It is possible to conclude that the public PVO pumps have suffered from the increased PVO price as a result of high feedstock prices and the ending of tax exemptions.

5.1.3. Advanced biofuels

As a consequence of EU policy, the GAVE programme lost its role as an R&D funding programme and was assigned by the government to facilitate the government and various stakeholders in the implementation of biofuel in general (Tweede Kamer, 2005a). However, during this period a great number of new subsidy programmes financed advanced biofuels among other innovations. Table 8 provides an overview.

[39] www.biotanken.nl, visited on 2012.03.01

Programme	Aim	Period	Budget €	Receivers	Additional info
Economy Ecology and Technology (EET, Energie, Ecologie en Technologie)[40]a	To improve the environment and economic growth by means of technology innovation and breakthrough.	1997-2005	1997-2003 = 246 million 2004-2005= 70.6 million	Consortia involving companies, research institutes and universities	Biofuel was high on the agenda considering that the top technology areas funded were: chemistry (23%), energy (18%) and the environment, transport and foods (each 10%)
Energy Research Subsidy (EOS, Energie Onderzoek Subsidie)[41]	To stimulate knowledge production on energy efficiency and sustainable energy, from idea to demonstration and market introduction.	2004-2011	EOS NEO feasibility: 0.5 million EOS KTO: 1 million EOS NEO research: 0.7 million EOS KTO: 7.6 million EOS DEMO: 7 million[42]	Researchers and innovators at companies, research institutes and universities	Four subsidy schemes: New Energy research (EOS NEO), Long-term research, (EOS, LT), short-term research (EOS, KTO) and demonstration (EOS DEMO)
Sustainable Energy Netherlands (DEN, Duurzame Energie Nederland)[43]	To stimulate sustainable energy solutions (the application of bioenergy, solar energy, heat pumps, geothermal heating and wind energy.	2002-still active	No financial support, only by means of knowledge and networks	Various actors	
Green feedstock (Groene grondstoffen)[44]	To stimulate sustainable production/ import, processing and implementation of biomass in order to develop a bio-based economy.	2003-2012[45]	30 million	Various actors	Initially, activities seem to have taken place at the University of Wageningen alone. In later years, the programme has been broader and open to companies.

Table 8: Main subsidy programmes for advanced biofuels

[40] (Senter, 2004; Tweede Kamer, 2001)

[41] (Dynova, 2012)

[42] (Biomassaforum, 2012)

[43] (Agenschap NL, 2012)

[44] (Biobased Innovations, 2012)

[45] A new programme with the same name that is continuing until 2012, indicative total programme funds € 30. Initially (2003-2006) seemed to take place at the University of Wageningen only (WUR, 2012).

Cellulose ethanol
While the previous period saw only a few active subsidy programmes supporting cellulose ethanol, such as the EET Kiem programme focused on fuels and energy from bio residues, this period had a great variety of programmes supporting ethanol research. Table 9 presents an overview of the programmes and projects described in this section.

Programme	Biofuel project name/focus	Year	Description
EET	Co-production of bioethanol, lactic acid, electricity and heat from lignocellulosic biomass	2002-2006	Nedalco-led projects on thermal mild acid pre-treatment in combination with enzymatic hydrolyses.
Green Feedstock	Ethanol from straw	?	
EOS NEO	Ethanol Production from (Ligno) Cellulose Materials	2004-2005	TNO-led projects on sulphuric acid ethanol processes excluding enzymes
EET	Biosuphurol process	2003-2007	Same sulphuric acid process excluding enzymes and additional high energy processes.
EOS	An alternative two-step fermentation route	2004-2005	Wageningen University-led acid ethanol process with alternative fermentation route
EOS Long-term.	N-ergy microbiological co-production of N-chemicals and ethanol from biomass fractions	2006-2009	University of Wageningen-led biorefinery process involving ethanol production.
EOS Long-term.	Value-added valorization of lignin for optimal biorefinery of lignocellulose for energy carriers and products	2007-2010	
EOS Long-term.	Maximizing the bioenergy potential of lignocellulose biomass; mitigating the effect of humic and fulvic acids.	2007-2010	
EOS Long-term.	Towards bioethanol from sugar beet pulp: the pectin challenge	2007-2010	Nedalco-led project on biorefinery/ethanol.
EOS, NEO and other EOS subsidies	Ethanol from Synthetic Natural Gas (SNG).	2004-2005, 2005-	TU Eindhoven-led project on ethanol from synthetic gas
EOS Long-term.	Biobuthanol fuel a chemical additive	2005-2008	Agrotechnology and Food Innovations B.V. (A&F) project on biobuthanol.

Table 9: Various ethanol related research projects and subsidy programmes

As is outlined above, the 2003 EU Biofuel directive triggered the Dutch government to stimulate not only conventional fuels, but also advanced fuels. On ethanol development, various ministers endorsed Nedalco to set up the Nr One project. As is outlined in the conventional biofuel section above, the aim of the project was to start production of ethanol from waste materials based on starch and slowly transfer to ligno-cellulose biomass. The vision set out was to develop ligno-cellulose ethanol experiments in 2004-2005 and to have ethanol widely used as a climate neutral transport fuel by 2040. While the initiatives to set up ethanol production based on starch never came about, the activities directed towards the development of ligno-cellulose ethanol technology advanced.

Nedalco in collaboration with the Ministry of Housing, Spatial Planning and the Environment, the research institutes ATO and LEI at Wageningen University, TNO, TNO MEP and the consultant companies Bird Engineering and Belmont took the lead in cellulose ethanol activities. The idea was that the new ethanol technology had great potential for the Dutch Knowledge Society and the port of Rotterdam due to its wide and international applications. To enable a transition to cellulose ethanol, the project partners suggested three activities. First, in 2004 the network should organize a societal discussion with regard to the application of Genetically Modified Organisms (GMOs). This was necessary since genetically modified yeast was part of the fermentation of C5 sugars in cellulose feedstock to ethanol. Second, in 2004 the network set out to research the bottlenecks in the cellulose ethanol production process, and to set up a factory trial in late 2005. The bottlenecks related to the pre-treatment of biomass, enzymatic hydrolysis and the fermentation of C5 sugars. The third network activity was to obtain long-term organization and financing. The organization and financing was necessary for the short-term activities mentioned above, as well as other activities needed to facilitate the transition in the long term. For an ethanol transition scheduled for the coming 10-20 years, a budget of € 0.5 to 1 billion was considered necessary (Nedalco, 2003).

Nedalco reported that the activities within the Nr. One project had been successful. In July 2004, the network announced the isolation of a fungus living in the intestines of elephants. They transferred the genetic code of this fungus into yeast, which could convert woody sugars, xylose, into ethanol. Researchers at the University of Delft and Nijmegen developed the technology and Nedalco patented the process (GAVE, 2004f). According to Weissmann, a spokesperson for Nedalco, Nedalco bore the costs of the two-year project which resulted in the isolation of the enzyme (Nedalco, personal communication, 18.10.2005) . In 2004, Weissmann stated that they could implement the technology in a broad application as early as 2010, if sufficient government funding were made available (GAVE, 2004f).

A parallel project to the No One project was the ‘Co-production of bioethanol, lactic acid, electricity and heat from lignocellulosic biomass’. This was a follow-up to the two EET Kiem ethanol research projects by Nedalco in the previous period (Reith & de Bont, 2007).[46] The new EET project had a budget of € 6 million for the period 2002–2006 (Senter, 2006). According to an employee at TNO (personal communication, 11.07.2008), the EET funds covered approximately 60 per cent of the total investment, while the rest had to be covered by matching funding from the various partners in the project (ibid.). The aim was to develop ethanol and lactic acid from biomass waste streams. The waste stream selected for the project was wheat straw. In practice, the project had to deal with several bottlenecks, such as pre-treatment, enzymatic hydrolysis, fermentation of hydrolysates, co-generation of electricity in ethanol production and the isolation of new fermentative organisms. The same Nedalco research alliance also cooperated on this programme. In addition, TNO, the chemical company Purac and Shell Global Solutions joined the project. The project managed to demonstrate the feasibility of producing ethanol and lactic acid from wheat straw. The ethanol trial ran successfully at the lab-scale and later in a pilot (Reith & de Bont, 2007). In July 2005, researchers from Wageningen managed to convert 25 kg of straw into ethanol. This was the first time ethanol had been produced from straw in the Netherlands (GAVE, 2005u). In addition, they carried out a Life Cycle Analysis LCA, which showed that ethanol from straw had increased environmental performance compared to other alternatives (Reith & de Bont, 2007). Additional funds granted to the ethanol research cluster in the same period facilitated the success of the EET project. In particularly, the Groene Grondstoffen (Green Feedstock) programme financed by the Ministry of Agriculture, Nature and Food Quality (LVN) contributed to the project by allocating funds for the development of ethanol production

[46] The two earlier EET Kiem projects led by Nedalco were 'GFV/WLL – Procede', an ‘explorative study of the commercialization of cellulose ethanol’ and ‘ThermoZym, cellulose conversion for the production of ethanol’, outlined in the previous period.

(GAVE, 2005u). According to a biofuel expert at TNO (personal communication, 11.07.2008), the success of the EET project helped make Nedalco the main proponent of the ethanol conversion process developed by the project, which focuses on thermal mild acid pre-treatment in combination with enzymatic hydrolyses. Nedalco set out to implement the process in a plant, but it did not have sufficient means to finance the advanced plant or the expensive enzymes necessary for the production process (ibid.). The high level of expense and the lack of collaboration with actors that could provide the other vital processes of ethanol production might explain why Nedalco did not manage to build a plant.

In parallel with the cellulose ethanol production processes led by Nedalco, focused primarily on mild acid hydrolyses in combination with enzyme technology, other actors started projects based on an alternative production route. These excluded enzymes and focused solely on acid hydrolyses processes. TNO was one of the initiators of this production process, focusing on sulphuric acid.

In cooperation with the financial consultancy firm Hazewinkel Beheer, the research institute ATO, the Port of Rotterdam and the refinery Nerefco, TNO initiated testing of an ethanol production process based on sulphuric acid technology. In December 2003, it concluded that the sulphuric acid process could reduce the production costs and therefore price of ethanol drastically. According to TNO, the production cost of one litre of ethanol would be € 0,15 compared to the current cost of € 0,35-0,50 (GAVE, 2003e). Consequently, the research institute TNO-MEP47 carried out additional research on cellulose ethanol focusing on acids in the period September 2004 to July 2005. The project, Ethanol Production from (Ligno) Cellulose Materials, gained funds from the Energy Research Subsidy (Energie Onderzoek Subsidie, EOS) programme (SenterNovem, 2009d), which subsidized activities that aimed to contribute to renewable energy and fuel technology development (Kimman & Soeriowardojo, 2009). The project aimed to extract glucose from cellulose by mixing ethanol and water at high temperature and under high pressure in a slightly acid environment. The idea was to circumvent the enzyme technology, which was one of the main bottlenecks in the development of cellulose ethanol (SenterNovem, 2009d). The sulphuric acid process was later developed into the so called 'Biosuphurol process' by researchers at TNO and Wagningen, which gained funding from a four-year EET programme in 2003 (van der Meer, 2009; Van Groenestijn, Hazewinkel & Bakker, 2007). TNO researchers argued that this process was more energy efficient than the previous acid sulphur process, because it excluded expensive enzymes and the need for a high pressure and high temperature environment for the pre-treatment of the cellulose. The experiments carried out with the Biosuphurol process with feedstock such as willow and switch grass showed that the process could deliver cost efficiencies close to 80 per cent. The researchers saw the possibility of increasing energy efficiency even more if the process heat as well as the sulphuric acid could be recycled. The latter is still a process under development (Van Groenestijn et al., 2007). Based on the positive results of the Biosuphurol process, two energy industry professionals, van der Lugt and Shipway, set up a company, New Leaf, in the UK. The ambition of the company was to commercialize the Biosuphur process by setting up a plant at a port, either Rotterdam, Amsterdam or Eemshaven, in the Netherlands (GAVE, 2009e).The aim was to produce ethanol for the transport sector and so-called bio-coal for energy production. The raw material for bio-coal production was the waste product lignin, which results from the ethanol production process. New Leaf argued that the use of ethanol and bio-coal was a good way to

[47] TNO-MEP is one of the 14 institutes of the TNO organisation and is committed to quality living conditions, competitive production processes and sustainable use of energy. To this end TNO-MEP develops and applies knowledge and innovative technologies.

meet CO_2 reduction goals without threatening food production. The scientists who developed the process at TNO (van Groenestijn) and Wageningen (Bakker) provided scientific advice. To facilitate the construction of the plant, New Leaf consulted Hazewinkel and its engineering company Techno Invent B.V. for technical expertise (New Leaf, 2009). New Leaf expected the plant to be ready for production in 2013, with an annual output of 200 million litres of ethanol and 220 000 tonnes of lignin (biocoal) from 650 000 tonnes of biomass (GAVE, 2009e). According to Biosulfurol Energy (2010), which is the new company name of New Leaf Energy, a plan to start biosulphurol production is still on the agenda.

Wageningen University carried out a parallel project on acids between April 2004 and 2005 by using funds from the EOS programme. The researchers proposed an alternative fermentation route in order to avoid expensive sugar containing feedstock, and hydrolyse processes. This route uses a two-step process. First, a combined hydrolysis and fermentation in a so-called acidification process, which converts organic material into fatty acids. Second, a 'bio-hydrogenation' process, which converts the fatty acids to ethanol. The project aimed to demonstrate proof in principle of this conversion process (SenterNovem, 2009g). Despite the early start, there has not yet been any reporting on this project.

A new trend that appeared in the previous period and gained increased attention in this period was a focus on the most efficient use of the different parts of the biomass feedstock. This implies that all biomass should primarily serve the production of higher quality products, such as food and chemicals, while the leftovers from this process may serve energy products such as biofuels or animal feed. The bio-energy sector calls this process 'bio-refinery' (Eindhoven University of Technology, personal communication, 15.01.2007) (Daey Ouwens, 2007). Many of the projects listed above used the same principle, but by the end of this period some projects referred to the process explicitly. An example of the latter was an initiative by Sanders at Wageningen University. In collaboration with ECN, the German Westfälische Wilhelms Universität Münster and the agrarian advisory bureau Easthouse Business Solutions B.V., Sanders managed to set up the project 'N-ergy microbiological co-production of N-chemicals and ethanol from biomass fractions'. The aim of the project was to develop a bio-refinery route for co-production of feedstock for bulk chemicals and ethanol. Sanders and his partners saw nitrogenous chemicals and biofuels or bio-energy as dependent on a particularly energy-intensive production process. By using a bio-refinery process, they expected that the energy efficiency of ethanol production would increase two or even four fold. The bio-refinery process investigated for this project was a fermentation technology. The ability to use this technology on a large scale was the object of investigation. Funding for the project was gained from the EOS subsidy 'Lange Termijn', focusing on projects with a long-term focus. The project started in January 2006 and was expected to finish in December 2009 (SenterNovem, 2009f).

Wageningen University initiated related projects, of which one was 'Value-added valorization of lignin for optimal biorefinery of lignocellulose towards energy carriers and products'. This project focused on lignin, a waste product from producing ethanol from cellulose. The researchers argued that lignin was a suitable feedstock for the production of a variety of chemicals and chemical products. In line with the bio-refinery concept, they argued that the development of bio-refinery processes could take care of the lignin and increase the energy and cost-efficiency of ethanol production and thus also speed up the cellulose ethanol development process. The project started in January 2007 and received financing to the end of 2010 from the EOS long-term subsidy (SenterNovem, 2009e). In parallel with this project, another project, 'Maximising the bioenergy potential of lignocellulose biomass: mitigating the effect of humic and fulvic acids', was running at Wageningen University. The project aimed to optimize the cellulose hydrolysis process, which would make the production of either ethanol or methane more efficient. This project was also funded by the EOS long-term subsidy (SenterNovem, 2009h).

A third project, 'Towards bioethanol from sugar beet pulp: the pectin challenge', began in January 2007, funded until December 2010. Nedalco coordinated the project. It aimed to use sugar beet pulp as a source for ethanol production. Sugar beet pulp is a residual of sugar beet processing that contains cellulose, hemicellulose and pectin. The large proportions of pectin and of particular acids were problematic in the process of ethanol conversion. To tackle these problems, Nedalco enrolled additional actors, such as Dyadic Nederland B.V., a specialist in microorganisms and enzymes; the Universities of Wageningen and Delft; and ECN. Nedalco, which used sugar beet in its alcohol production process, aimed to put the beet pulp process into practice. This project also gained funds from the EOS long-term subsidy (SenterNovem, 2009c).

In addition to the various cellulose ethanol-processing paths, including biorefinery routes, an unexpected ethanol production route gained attention – ethanol from Synthetic Natural Gas (SNG). This was an initiative taken by Han van Kasteren at the Technical University of Eindhoven. The University of Eindhoven carried out the project in collaboration with Ingenia Consultants and Engineers, focused on technology, the environment and the economy, and Telos, the centre for sustainable development in the Brabant region. The NEO subsidy of the EOS programme sponsored the project from November 2004 to September 2005. The results from the experiments showed that ethanol production via a gasification and fermentation route was competitive with known cellulose fermentation technology. The expected price of the ethanol gasification route was € 0.60 per litre of ethanol. An advantage of the gasification route is that it can treat all kinds of biomass, even waste streams (Van Kasteren, Dizdarevic, Van der Waall, Guo and Verberne, 2005). The study attracted great interest from international researchers and the ethanol production industry, such as Abengoa and ADM. Follow-up funds were gained from EOS to develop the process further, but the main bottleneck remained the gasification technology. In recent years, Van Kasteren has set up a new collaboration with Delft University and Chinese partners in order to realize a pilot installation and carry out further research on the SNG-ethanol process (Eindhoven University of Technology, personal communication, 30.07.2010).

Another, less conventional, cellulose alcohol-related R&D activity in this period was experimentation with a novel fuel and chemical additive called 'bio-butanol', which ran from September 2005 to September 2008. Innovations in fermentation and the breaking up of sugars in cellulose led to the idea of bio-buthanol. The project aims to assess the potential economic and ecological gains from this alternative alcohol fuel and to produce butanol for € 250/m^3. The Agrotechnology and Food Innovations B.V. (A&F), which is a business unit of Wagening University, initiated this project in cooperation with ECN. A stakeholder group of companies related to the bio-buthanol chain was set up to perform a critical evaluation (SenterNovem, 2009a). The results from this project are not yet clear.

With regard to international initiatives in this period, two projects are visible in the literature. The first was a European research project led by Nedalco in collaboration with several Dutch and international partners, including Lund University in Sweden and the research institute VTT in Finland (Van den Broek et al., 2003). There has been no publication or announcement of the results of this collaboration. However, Shell was involved in a second more long-lived international project. In 2002, Shell started to collaborate with Iogen, a Canadian company that was and still is at the forefront of cellulose ethanol development. The collaboration involved an equity stake of 26 per cent in the Iogen Corporation. In 2004, Iogen was the first company to set up a demonstration plant producing ethanol from wheat straw. In 2008, Shell increased its investment in cellulose ethanol technology by raising its share to 50 per cent of the Iogen Corporation. The same year, Iogen delivered 180 000 litres of cellulose ethanol to Shell. The increased collaboration with Iogen aims to accelerate the development of a large-scale commercial cellulose ethanol plant (Royal Dutch Shell, 2008). Since 2009, the renewable focus within Shell has moved increasingly towards biofuels for energy and transport solutions, while solar and wind have fallen off the agenda. However, while the collaboration with Iogen persists, a recent development indicates that Shell has more interest in other biofuels with a better fit with its storage infrastructure and engines than ethanol. Another reason for showing less interest in ethanol argued by the Shell General Manager for Alternative Energies and Fuel Development, Reijnhart, was persistent problems with achieving commercial production. In 2011 he argued 'The challenges of up-scaling cellulosic ethanol in a commercially viable way and with reliable processes are enormous' (Lane, 2012).

Fischer Tropsch

A number of research programmes and projects were initiated on FT-diesel and its related syngas processes. These are listed in Table 10.

Programme	Project name/focus	Year	Leading actor
EET	Fischer-Tropsch synthesis based on oil produced by a pyrolysis gasification process	2001-2003	Biomass Technology Group (BTG)-led experiment with Shell
EOS NEO	First evaluation of various SNG technologies	2002	ECN-led feasibility studies on SNG and FT-diesel
Novem DEN	Feasibility of SNG and FT-diesel coproduction	2003	
EOS DEMO	Application of OLGA gasification	2006-2008	Dahlman-led project using OLGA in gas motors, later in cooperation with ECN
EOS Long-term	Processes to remove tar in SNG production	2005-2007	BTG-led experiment on tar removal
EOS	Gasification of wet biomass in supercritical water	2007-2010	TNO-led project that applied a modified HTU process for SNG production to avoid tar production
Senter Novem DEN	Milena lab-scale and pilot plant	2002-2008	ECN-led lab-scale demo and pilot of indirectly heated air-blown gasifier technology, Milena, which could be combined with the OLGA gas cleaner
EOS	BioGG, Milena demo plant	2006-2008	ECN-led feasibility experiment of Milena demonstration plant

Table 10: Various FT-diesel related research projects and subsidy programmes

In the previous period research activities on FT-diesel within the GAVE programme were ended because of persistent bottlenecks such as bio-SNG cleaning, which the project partners could not resolve within the short-term time frame and with the limited funding provided. Nevertheless, given that FT-diesel experiments were continued by government funded research organizations such as ECN in this period, it seems likely that the promise of FT-diesel remained high.

In cooperation with Shell, ECN continued research in this period on gas cleaning using fluidized bed gasification technology. In 2001, an SNG tar removal test installation, OLGA, was set up at ECN in Petten. In December 2003, ECN demonstrated the successful production of SNG (Boerrigter, Calis, Slort and Bodenstaff, 2004). Financing from the NEO programme enabled the development of OLGA into a successful tar removal device (SenterNovem, 2005c). The ability to produce clean SNG was an international breakthrough for the gas sector. As a result, ECN set up plans for a large-scale test installation for SNG production together with the Dutch gas company Gasunie (GAVE, 2004b).

With this breakthrough in gas cleaning, the promise of FT-diesel production returned. It was not only the cooperation between ECN and Shell that was still live. The old BIG-FIT network built up in relation to the GAVE programme was also still intact. A newcomer was added to this network – the consultancy firm Ecofys. In late 2003, Ecofys presented research results showing that the BIG-FIT process could deliver more than 90 per cent CO_2 reductions, and that the production costs of FT-diesel would only be € 0.39 per litre. They argued that the only bottleneck was the fact that there was no large-scale gasification installation available. The latter was crucial since only a large-scale plant could make the promise of low-cost fuel production possible (GAVE, 2003b). According to Daey Ouwens and Küpers (Daey Ouwens & Küpers 2003 260 /id) the process could become even more cost efficient and result in a cost price of € 0.25-0.30 per litre. In a more critical report published in 2004, ECN and Shell argued that the BIG-FIT technology was immature, which prevented short-term commercialization. In order to meet the EC biofuel target for 2010, the report authors argued that an investment of approximately € 25 billion would be needed. The resulting product would be 2-3 times more expensive than fossil diesel. Despite this, ECN argued that the positive environmental impact and the commonly held belief that first-generation biofuels were limited by the availability of feedstock was sufficient motive to continue R&D on FT-diesel (Boerrigter et al., 2004). Hamelinck et al. (Hamelinck, Faaij, Den Uil and Boerrigter, 2003) agreed that the high costs of producing FT-diesel was the main barrier in the short term. Nevertheless, they argued there would be cost reductions within 15 years (by 2018). Moreover, while FT-diesel might become more expensive than hydrogen and methanol, FT-diesel benefits from a perfect fit with conventional diesel infrastructure.

There was the formation of two camps with regard to the future of FT-diesel . On the one hand, the more hesitant position taken by Shell and ECN due to the expected high costs and, on the other hand, scientists and public biofuel proponents such as Daey Owens, Faaij and Hamelinck which were more certain about the positive potential of the technology. According to Daey Ouwens (2007) (see also Eindhoven University of Technology, personal communication, 27.01.2007), FT-diesel production technology was proven and no longer had any severe technical barriers. He argued that the decision to discontinue the BIG-FIT project and set up an FT-diesel plant was due to Shell's withdrawal from the project. This according to Daey Owens was proved by the fact that Shell did not invest in the Dutch project, but exploited the lessons learned through Dutch government subsidized studies for its own profit. Shell invested in twelve coal gasification plants in China based on the same gasification technology that they had been experimenting with in the Netherlands.

However, Shell's withdrawal from the BIG-FIT project did not mean that Shell gave up FT-diesel. In parallel with the development of the BIG FIT project, Venderbosch from the Biomass Technology Group (BTG) led an experiment with Shell on Fischer-Tropsch synthesis based on oil produced by a pyrolysis gasification process. The EET Kiem programme financed the experiments from 2001 to 2003 (SenterNovem, 2005b). There are no reports of the results of the programme, which could indicate either a failure or that the results were commercially sensitive.

In addition to the Dutch projects, Shell started bio-based FT-diesel projects abroad. In 2005, Shell invested in a German company, Choren. The investment was equal to 25 per cent of Choren's shares. The reason for this investment was Choren's SNG technology, Carbo-V, which was advanced and ready for implementation in the commercial production of FT-diesel, called SunFuel in Germany. The construction of a factory in Freiburg that produces FT-diesel from wood and plant waste was scheduled for 2007 (GAVE, 2005t). Volkswagen and Daimler were also stakeholders of Choren, which meant that they also contributed to the construction of the plant. In April 2008, the plant, named the Beta plant, was ready for operation. It had a capacity of 18 million litres, but even at this stage Choren was making plans to scale up the plant. Since the Beta plant had to start up slowly, unit by unit, full production would take some time (Volkswagen Group, 2008). In November 2009, Shell sold its shares in Choren. Shell did not reveal the reason for withdrawal, but the fact that the start-up process was still ongoing may have contributed to its decision. In the same press release, Choren and Shell announced that they would continue to collaborate on the development of FT-diesel technology (Choren, 2009). While Shell sold its shares in Choren, it did not lose interest in FT-diesel. About the same time, Shell returned to FT-diesel collaboration in the Netherlands.

During the collaboration between Shell and Choren, the Dutch FT network linked to the GAVE programme met again to discuss the potential for FT-diesel production. It was Shell and Nuon that started a feasibility study on FT-biodiesel production at the Buggenum IGCC plant (van der Meer, 2009). Buggenum was the same plant that was set up for future FT-diesel production during the GAVE programme. It is still too early to say what the results are from this study. However, to a certain extent interest in the development of bio-based FT-diesel in the Netherlands remains among industrial actors. However, given that neither Shell nor any other industrial actors have made any large-scale investments in the technology, continued technology development is likely to be dependent on government funds.

As is outlined above, successful production of FT-diesel was dependent on a working SNG process. In this period, developments in SNG technology were driven not only by the production of liquid fuels, such as FT-diesel, but also by the substitution of natural gas in the production of heat and electricity. A study published by Mozaffarian and Zwart (2003) from ECN funded by the EOS NEO programme, evaluated the different SNG techniques for the first time. The study concluded that SNG was worthwhile, from both an environmental and an economic point of view. The most promising technologies were: first, the upstream pressurized oxygen-blown gasification; and, second, indirect gasification with downstream methanization. In a follow-up study, Boerrigter and Zwart (2004) at ECN, supported by Novem's DEN programme, researched the technical and economic feasibility of co-production of FT-diesel and SNG. The reason for this research was the discovery of a by-product in the FT synthesis – a high quality SNG gas. Based on this discovery, conversion of the SNG by-product to high quality natural gas was easy, and Boerrigter and Zwart (2004) concluded that FT-diesel and SNG co-production was more cost-efficient than separate production processes. Moreover, they argued that these technologies could become economically feasible if both SNG and FT-diesel gained the same tax reductions as those currently given to green electricity. The estimated CO_2 reduction costs ranged from € 99-175 per tonne.

These early studies gave the impression that the development of SNG technology was proceeding successfully, but engineers had not yet managed to resolve the major bottleneck of tar removal. According to the Dahlman Industrial Group, which had worked on the OLGA technology together with ECN, the OLGA tar removal technology only worked at the pilot scale. When they used the technology in gas-motors for electricity generation, it failed. Hence, to improve the gas cleaning technology, the EOS: DEMO subsidy programme focused on financing new demonstration projects from 2006 to 2008. The first project Dahlman carried out alone. It focused on the application of OLGA in gas motors. In a second project, Dahlman cooperated with ECN on larger scale application of the OLGA technology at a site in France (SenterNovem, 2006b; SenterNovem, 2007b). BTG also started to experiment with the tar removal technology developed at ECN by means of the EOS long-term subsidy. BTG's hypothesis was that quickly heated gasification would result in a clean SNG without tars. BTG ran the project from 2005 to 2007 (SenterNovem, 2005a).

Finally, a new actor, TNO, decided to tackle the tar problem from another angle: it chose a process that did not produce tars. Based on a technology evaluation by BTG (Van de Beld, Van Hutten and Kokke, 2004) financed by the EOS NEO programme, hopes were raised with regard to a new technology – gasification of wet biomass in supercritical water. This process was a modification of the HTU process. The main difference was that the conventional HTU process resulted in biocrude while the new process resulted in a synthetic gas. According to the project information on the website of Senter Novem (SenterNovem, 2006c), TNO initiated an EOS financed gasification project on wet biomass in supercritical water, which ran between January 2007 and 2010.

While TNO choose another gasification route, the shortcomings of OLGA did not stop the promise of conventional biomass gasification at ECN. ECN initiated a new project with Gasterra and Gasunie on SNG production based on the OLGA technology. The platform New Gas, part of the Energy Transition, formed the advisory board for the project. Part of the know-how came from the Senter Novem DEN programme. The project built an indirectly heated air-blown gasifier technology, Milena, in lab-scale format at ECN in Petten in 2004 (Zwart, Boerrigter, Deurwaarder, van der Meijden and van Paasen, 2006; ECN, 2008b). Using Milena, ECN could test the potential for developing quality SNG in combination with the OLGA technology. The conclusion of the project was that the SNG technology still had to increase its efficiency. One of the core barriers to market implementation was efficient gas cleaning, including tar removal. The project advised additional R&D activities to reach this goal. Despite the prevailing bottlenecks, the EOS long-term biomass gasification programme went along with these recommendations and listed SNG production as one of its targets. EOS explained this by arguing that SNG was a very important option for the Netherlands in order to create the sustainable production of heat, power and transportation fuels for the future. Moreover, according to ECN, the SNG experiment was successful enough for the implementation of a pilot plant of 800 kWth (Zwart et al., 2006). In the summer of 2008, the 800 kW pilot plant constructed at the ECN estate in Petten started operating. Even before the pilot plant was ready for operation, ECN was making plans for a 10MW Milena demonstration plant (ECN, 2008b). An experiment was set up with the Milena technology in order to check the feasibility of a 10MW demonstration plant. The aim was to convert biomass to bio-SNG with an energy efficiency of 75%. The name of this project was BioGG. ECN coordinated the project and enlisted the University of Twente, the University of Groningen and Halder Topsøe, a specialist in catalysts for the energy sector, as cooperating partners. Furthermore, a stakeholder group steered the project with actors from Energy Valley, Philips, natural gas companies Gasunie, Cogas, DutCH4, the energy company ENECO, the Province of Friesland, the organization managing the Dutch natural reserves, Staatsbosbeheer, and the employers' organization for professional transportation of goods and people – Royal Dutch Transportation (KNV), among others. EOS funded BioGG from January 2006 to 2008. This is no surprise given its expressed preference for SNG. The suggestion of the BioGG project actors was to follow-up this project with a demonstration plant. The plan was to build the demonstration plant, with equally good energy efficiency, in the Energy Valley region in the north of the Netherlands (ECN, 2008b). The results of the BioGG project seemed promising, since the high promise of the gasification technology remained in the final year of the project. According to ECN (2008b), the flexibility of the gasification technology feedstock and its wide application, to energy, heat or types of transport fuels, was still one of the most attractive qualities of this technology. Moreover, at ECN, the OLGA technology was still considered the solution for gas cleaning and was expected to be connected with the Milena technology in the planned plant (ECN, 2008b).

More recently, the demonstration plant has become known as a Bio-Methane demonstration, aiming for a plant with 12 MW feedstock capacity instead of the initial 10. Changes in the plans, extension of the consortium and a possible change of location have delayed the project somewhat, which now has a target to start production in 2013. Of the additional actors that have joined the consortium, the core actors are ECN, Dahlman and the public service waste and energy company HVC Group. In addition to ECN's Milena gasification technology, Dahlman will provide the OLGA tar removal technology and HVC the waste feedstock. The location will be Alkmaar and the expected output of Bio-Methane is 0.01 billion cubic meter per year. The demonstration plant will also deliver heat to the district heating grid. There are plans for a follow-up plant of 50 MW or 0.04 bmc/year, which is seen as the minimum size for a commercial bio-SNG plant (ECN, 2011).

At the end of this period, the aim of SNG development was mainly to produce a potential substitute for natural gas, and therefore a source of heat and electricity (see Energy transition, 2009). Actors interested in the development of transport fuels from SNG mainly had FT-diesel in mind, as in the case of the Milena-OLGA pilot plant. With regard to the development of gas vehicles, SNG was an option that was gaining attention but still not as much as FT-diesel. In the activities of the working group Driving on Natural Gas and the Biogas part of the Sustainable Mobility Platform (Platvorm Duurzame Mobiliteit, 2009), biogas based on conventional technologies such as anaerobic digestion was the only gaseous biofuel promoted. The working group had scheduled experiments with vehicles on biogas for 2009. However, according to the biofuel initiatives listed by GAVE (2012), there were initiatives with biogas vehicles in Leiden in 2008 and several biogas production sites connected to waste water plants emerged at about the same time (ibid.). In the description of conventional biofuel projects above, activities indicate a growing interest in biogas. Even though many of the biogas projects were related to energy production, the fact that the majority of the 2009 TAB subsidy of € 3.6 million for the construction of biofuel refuelling pumps was going to biogas indicates the growing interest in biogas vehicles (SenterNovem, 2010b; Interprovincial Overleg, 2010).

In the future, if SNG production becomes commercially viable, driving on SNG may be of interest. Biogas and bio-syngas were together referred to as 'green gas' by the members of the Sustainable Mobility Platform (Platvorm Duurzame Mobiliteit, 2009). However, as of 2012, the platform had only stimulated a new but more conventional practice – driving on natural gas (GAVE, 2012; Platvorm Duurzame Mobiliteit, 2009). This, according to the platform, was intended to work as a stepping stone for biogas implementation (Platvorm Duurzame Mobiliteit, 2009).

HTU

Activities in the field of HTU technology, which in the previous period were sponsored by the GAVE programme, were followed-up in this period. There were also different funding programmes, as indicated in Table 11.

To enable the continuation of research activities, TNO managed to gain know-how from the DEN programme and financial support from the Shell Research Foundation. In 2004, after running three-week trial of feedstock union pulp, TNO concluded that the pilot plant in Apeldoorn had successfully managed to produce raw biocrude. Shell Research enabled the additional tests to be carried out at the pilot plant with alternative feedstock in order to further commercial development of the HTU process. During the project, the project partners changed slightly. The new network was composed of the municipal waste combustion company of Amsterdam, Afval Energie Bedrijf Amsterdam (AEB), Shell Research, TNO Science and Industry and Biofuel B.V. Due to the success of the pilot trial, AEB expressed an interest in bringing the technology to a commercial stage. In addition, the TNO researchers recommended continuing planning and preparation for the set up of a demonstration plant. However, before commercialization, TNO suggested additional tests and research to optimize the process at the pilot plant. The demonstration plant that AEB had envisaged would have a capacity of 6 tonnes of biomass per hour. The existing pilot plant only had a capacity of 100kg of biomass per hour (GAVE, 2004a; SenterNovem, 2007d). Further information on the progress of AEB's demonstration plant is not available. A presentation given by the Biofuel B.V. company owners Goudriaan and Naber (2008) in 2008 indicated that Biofuel B.V. no longer supported the project. In fact, in this presentation, Goudriaan and Naber sketched the history of HTU without mentioning the TNO-AEB project (ibid.). This makes it likely that the project failed.

However, Goudriaan and Naber (2008) stated that the TNO pilot plant had produced the first biocrude based on organic household waste in 2006, indicating that trials at the pilot plant continued. Moreover, instead of the planned plant with AEB, in 2005 they started collaboration with the waste manager HVC Alkmaar and the French fuel distribution company Total. According to HVC Alkmaar (HVC, 2009), the aim of this project was to set up a HTU production facility based on organic household waste within a couple of years and to convert the biocrude to high quality biodiesel or bio-kerosene (ibid.). There has however been no news about this plant, which indicates that this initiative may also have failed.

Along with the mainstream HTU initiatives, an experimental initiative was undertaken by BTG which involved HTU. In 2006, BTG obtained a grant from the EOS NEO programme to research the simultaneous production of oil from the HTU process and the fast pyrolysis process. The grant was awarded for the period January 2006 to May 2007. Previous research showed the potential for the production of these two types of oil by means of thermal decomposition, by excluding oxygen in an environment of 30 °C. Hence, the aim of the BTG project was: first, to investigate the optimal quality of these oils in relation to the temperature of thermal decomposition; second, to research what potential efficiencies and cost reductions were possible compared to traditional biodiesel production; and, third, to examine the extent to which the process was more sustainable than other biodiesel production processes (SenterNovem, 2008).

Despite great promise, however, the HTU process still failed to scale up. This was a trend for all advanced biofuels at the end of this period. It is most clear in the declining expectations for FT-diesel, which was the most promising fuel in the previous period, while this period indicates declining interest in FT-diesel experiments and more focus on the pre-development process of SNG production. Nedalco's failure to build a production plant and Shell's reduced interest in cellulose ethanol indicate a similar downward trend for cellulose ethanol development. These developments are quite surprising given developments at both the EU and the national policy levels, which sought to stimulate CO_2 efficient advanced biofuels in particular with sustainability criteria and double counting measures.

Programme	Project name/focus	Year	Leading actor
Novem DEN, Shell	Pilot plant trial, preparation for demonstration plant	2004-	TNO-led experiments
	HTU production plant for biodiesel and bio kerosene.	2005-	Biofuel B.V.-led project
EOS programme NEO	Simultaneous production of oil from HTU and the fast pyrolysis process	2006-2007	BTG-led research

Table 11: Various HTU-related research projects and subsidy programs

5.1.4. SNM analysis, 2003-2010

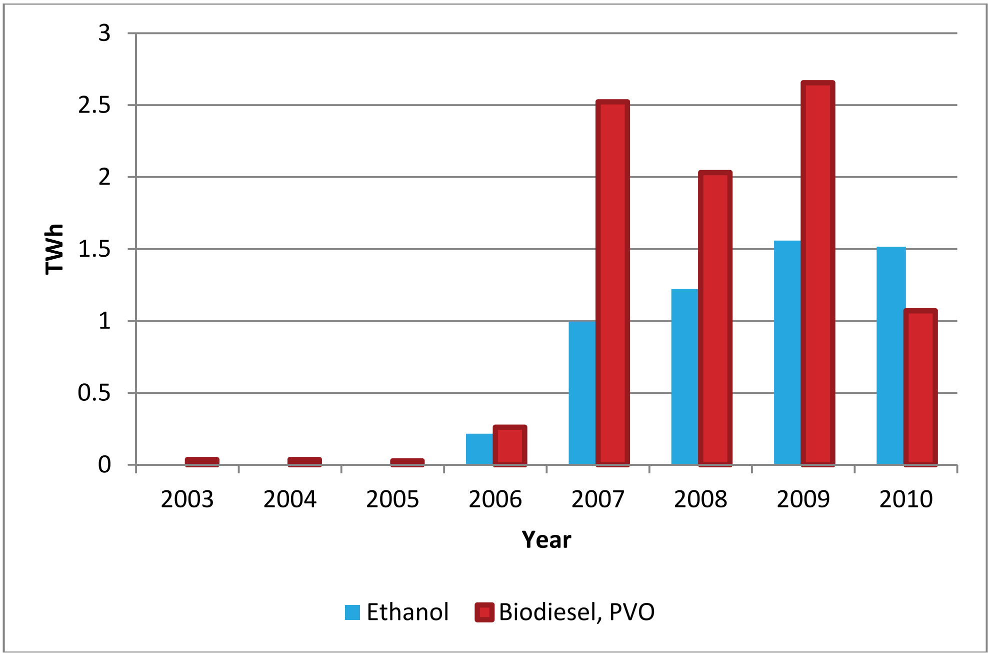

Figure 9: Consumption of ethanol, biodiesel and PVO in TWh, 2003-2010*
Source: Statistics Netherlands
* The vast majority of biofuels are used as low blends in fossil fuels.

Biofuel type	2003	2004	2005	2006	2007	2008	2009	2010
Ethanol Vehicles				Rotterdam FFV 6-30			5000	
Pumps				Argos oil E85				
						Various distributors E85		27
			Argos oil E5					
				Shell E5				
					All fuel distributors E5			
Plants/ import	Rotterdam harbour import							
			Vopak import					
			Sabic ETBE					
				Lyondell ETBE				
Biodiesel vehicles	H&R boats 14			H boats 14				
	P. Friesland boats 41							
	Kooij (previously K&P) boats 16							
	Gebranda vehicles 2							
	Staatsbos vehicles 10 + boat 1							
				TNT post vans 56				
						Conexxion buses <27		

					Various fleet trials			
Pumps			Delta Oil B100		Additional distributors B100 & B30			15
				Shell B5				
					All fuel distributors B5			
Plants/ import	Wiersma & other importers							
				Sunoil				
					Biovalue			
					Vierhouten Vet			
					Ecoson			
PVO vehicles	Aberson garage							
	Venlo street sweepers						3	
	McDonalds trucks							
	Fokkink oil presses and garage							
		Omrin street sweepers & trucks			25			20
		Flower auction street sweeper						
			BBA buses 2					
			SaWeCo truck					
			Maastricht street sweeper					
			Vitela/Van Leendert trucks					
			Noord-Beverland van					
			Polskamp					
					Rijschoon cars 14			
					Rijschool Nijland cars			
Pumps			Delta Oil	New Energy		Other distributors		10
Oil mills/ import	Various importers							
	Ger Groeneveld waste PVO							
		Opek oil mill, etc.						
			North Netherlands oil mill					
			Carnola oil mill, etc.					
			Achterhoekse oil mill					
				Twentsche oil mill				
						Polskamp waste PVO		

Table 12: Conventional biofuels, 2003-2010

Ethanol

Main network actors	Biofuel	Expectations	Key experiments	Learning	Socio-technical system building
Driving actor: Rotterdam municipality, assisted by oil distribution companies, Ford, International collaborations (BEST) and importers at Rotterdam harbour.	Ethanol import and use in FFVs and as low blend and ETBE	Environmental promise, mainly CO_2, commercial market promise. Stimulating external event: EU policy.	FFV niche starting in Rotterdam expanded quickly, accompanied by low blend expansion and trade in ethanol to the EU	ETBE good substitute for MTBE, low blend and FFV E85 work well. Problem with high feedstock prices	Largest market niche low blends, but also FFV market niche created with related fuel distribution infrastructure, pumps, storage, standards, etc. Supported mainly by local but also national financial incentives.

In this period actors' interest in ethanol returned. Rotterdam municipality led the main project. In collaboration with a leasing company, Ford, fuel distributors and ethanol producers such as Nedalco, Rotterdam municipality introduced an increasing number of ethanol FFVs and distribution locations. The project was also aided by an international network, BEST, in particular the Swedish network partners. Nedalco were to provide ethanol to the FFVs, which led to the re-emergence of previous plans for a conventional ethanol plant that could produce advanced ethanol in the future. However, Nedalco and others with production ambitions failed to compete with the ethanol import businesses and the chemical companies producing ethanol and ETBE from imported feedstock in Rotterdam harbour in an increasingly international market. The many committed actors and platforms for network collaboration such as BEST, Nr. One and GAVE indicate positive network development.

Of the *expectations* driving the initiatives, the promise that ethanol production and use would contribute to CO_2 reductions and reduce of fossil fuel use became increasingly important. This went hand in hand with expectations that a growing domestic and international ethanol market would create business opportunities for a variety of actors. In the ethanol case, the fuel traders and companies at Rotterdam Harbour were the main beneficiaries. Protection measures, such as the EU's biofuel policy, setting indicative biofuel implementation targets for the EU, and domestic biofuel policy stimulated these expectations. Low blend ethanol was stimulated when the domestic biofuel distribution obligation was placed on oil distribution companies. Other financial instruments, such as a one-year tax exemption and subsidies for ethanol distribution pumps, were more beneficial for the FFV niche. *Learning* from experienced international actors, such as Ford, or through collaboration within BEST helped to reinforce ethanol expectations, successful development of the FFV project and adoption of related ethanol standards.

Ethanol production from waste crops was particularly promising. However, the increasing price of food crops at the end of the period together with the lesson that sugar cane ethanol was cheaper and *more environmentally friendly* led to the termination of these plans. Instead, fuel importers took over the market.

The various actors, their activities and learning, together with government support, contributed to the creation of two ethanol market niches in this period: a large low-blend market niche and an FFV market niche with related standards, distribution and storage infrastructure.

Biodiesel

Main network actors	Biofuel	Expectations	Key experiments	Learning	Socio-technical system building
Municipalities, provinces and related fleets, boating companies, oil distribution companies, farmers' organizations and a variety of entrepreneurs interested in production and use. Initially high cooperation and network increase, but this is revised by end of period.	RME, pure use in boats, road vehicles and as low blend in diesel	Commercial market promise for low blend and pure use as a result of EU policy. Emission reduction mainly connected to CO_2 reduction. Promise of waste instead of crops as feedstock. General expectations reduced at end of period	RME in blends and pure in various fleets expands. Have to legitimize fuel production from crops, which leads to waste oil focus and import, and eventual decline of niche.	Technology lessons from pure and blended use, also production from crops and later waste oils. Legitimacy and financial support evident for niche expansion	Market niche in low blends with related production and distribution infrastructure. Growth and decline of pure biodiesel niche in vehicles, but this market niche more or less disappears.

The biodiesel boating network led by the Province of Friesland continued its boating experiments in this period. Additional *actors* providing farm vehicles joined the biodiesel trial. Separate from this network, many fleet owners tried to initiate biodiesel trials but only a handful were successful. Examples of successful fleets are those run by the public transport company Conexxion, the Dutch post and a variety of municipalities. As a result of the biofuel obligation, low blend distribution began and some fuel distribution companies complemented their distribution with pure fuel pumps and, at the end of the period in particular, high blend biodiesel pumps to assist the biodiesel fleets. In addition, imports increased and production facilities were set up to meet the growing market in the Netherlands and Germany. This led to an expansion of the biodiesel network, which like the ethanol niche indicated increased collaboration through platforms such as the Energy Valley which promoted pure biodiesel use, among other renewable fuels, and aided market expansion. In later years, however, more and more biodiesel and PVO actors ceased pure fuel experiments.

Like the previous period, network actors *expected* biodiesel to contribute environmental benefits. In this period, they stressed CO_2 reductions as well as potential business opportunities for biodiesel because of the known environmental benefits. Biofuel producers saw business opportunities in producing biofuel for the German market. As in the ethanol case, the EU biofuel directive and related Dutch biofuel policy stimulated the biodiesel expectations. However, hopes for a long-term tax exemption instead of a fuel implementation obligation hampered the development of some projects. An additional barrier was increasing feedstock prices, which contributed to the *lesson* that biodiesel production was not as profitable as initially expected. With this backdrop, the promise that waste oils and fats might be an alternative biodiesel feedstock emerged at the end of the period. This proved successful and resulted in a certain revival of biodiesel expectations.

The various processes resulted in expanded biodiesel use with a slight reduction in the last year of the period. This resulted in a large, low blend (B5) market niche and a smaller, high blend (B30) niche that had been created in addition to the existing, but heavily reduced, pure (B100) biodiesel niche. Related distribution and storage infrastructure had been set up as well as larger scale imports and limited domestic production which largely relied on waste feedstock.

PVO

Main network actors	Biofuel	Expectations	Key experiments	Learning	Socio-technical system building
Abersons leading, farmer organizations (NLTO), provinces, municipalities and a variety of fleets and entrepreneurs. Tight network collaboration, which is heavily reduced at the end of period.	PVO use in diesel vehicles	Promise of market expansion with EU Future for Farmers. Emission reductions, mainly local but also global. Promise reduced by end of period	Local production, North Netherlands oil mill main example, led to expansion of more oil mills and fleets, but need to fight for support. Development withdrawn as a result of high feedstock price and termination of tax exemptions.	PVO works, but funding decisive for niche survival. Like biodiesel, huge fight for legitimacy and support.	Temporary small vehicle market niche with infrastructure (production and distribution) that almost disappears at the end of period due to declining support.

The PVO *actors* and experiments expanded in this period under the lead of the Abersons. The number of farmers, municipalities and private fleet owners expanded. They developed a PVO mill and a related cluster of PVO fleets in the north and stimulated the creation of similar PVO production and user clusters all over the Netherlands. The latter indicates a particularly high level of collaboration and a growing network. However, by the end of the period, increasing numbers of actors left the network, resulting in a reduced PVO niche.

Expectations still referred to the local and global environmental benefits of conventional biofuel as well as its contribution to regional economic development and self-sufficiency. Farmers and a variety of municipalities in particular saw business opportunities in producing PVO for the Dutch and German market. An additional government tax exemption in 2005 complemented the long-term tax exemptions granted in the previous period. This particular tax exemption was unique and meant that PVO could not benefit from other biofuel incentives such as the biofuel obligation. Both the exemptions and continued *lessons* from Germany, leading to the adoption of German technology solutions, business ideas and standards, reinforced expectations in this period. However, like other biofuels, PVO actors suffered from high feedstock prices in 2008 which led to a collapse in PVO expectations, and of many projects due to their inability to compete with fossil fuels. The downward trend continued once government tax exemptions ended in 2011.

As a consequence of the above developments, the PVO network and fuel market reached their peak in the mid-2000s. By the end of this period, high feedstock prices and the expiring government tax exemptions led to a heavy reduction in the PVO market niche. The future prospects for PVO looked grim.

Biofuel type	2003	2004	2005	2006	2007	2008	2009	2010
HTU	Biofuel B.V./TNO			First biocrude				
			Biofuel B.V./HVC					
HTU/ Pyrolysis				BTG				
FT-diesel	BTG, Shell							
	SDE							
			Shell-Choren			Beta pilot		
							Shell-Nuon	
SNG	ECN OLGA pilot							
		ECN Milena pilot				larger pilot		
Cellulose ethanol	Nedalco		Pilot plant					
	TNO					TNO/New Leaf		
		U Wageningen						
		TU Eindhoven						
			A&F					
	Shell-Iogen international							

Table 13: Advanced biofuels, 2003-2010

Advanced biofuels

Main network actors	Biofuel	Expectations	Key experiments	Learning	Socio-technical system building
Universities, scientific institutes, industry, National (Nedalco, Shell, etc.) and international industry (Choren, Iogen). No collaboration biodiesel/oil and ethanol actors	HTU, cellulose ethanol, FT and SNG	Benefit global environment, more energy and cost-efficient, contribute to economic growth. Initially, high expectations despite failure to maintain promise, but expectations decline slightly by end of period due to persistent bottlenecks	Attempts to scale-up all biofuels at home or abroad. While technology advances, scale-up fails and national FT diesel development is replaced by SNG development	Technical lessons from all pilots, but bottlenecks (gas cleaning) and high prices prevail, which lead to lower expectations. New biorefinery techniques indicate reflexive lessons on how to go about lowering production costs	FT diesel, HTU and ethanol R&D niches

Scientists, research institutes and industry were still the central actors in the *network* for advanced biofuel options. The government agency, Novem, had a less active role, while collaboration with international actors such as Choren and Iogen was new. Ethanol actors, such as Nedalco, TNO and the universities, were increasingly devoted to cellulose ethanol development, which resulted in an ethanol pilot in 2005. Advanced FT-diesel researchers concentrated increasingly on gasification bottlenecks in collaboration with the energy niche. Towards the end of the period, industrial actors in both the ethanol and FT-diesel fields turned to international partners with more mature processes to develop production plants. HTU actors also had big ambitions to scale-up, which led to more advanced trials at the pilot plant and a search for new collaborations. Expanding networks for each biofuel were positive for niche development, but a remaining barrier was the limited collaboration across R&D networks.

Expectations for advanced biofuels still focused on large CO_2 reductions, higher energy efficiency and the availability of cheap biofuels in the long term. Despite the failure to live up to the ethanol and FT-diesel promises of technology demonstration in the previous period, advanced biofuel reappeared with visions of short-term demonstration projects and up-scaling. In addition, there was the growing promise of biorefinery processing – a search for the most efficient way to use feedstock and energy by means of co-production, which advanced biofuel actors expected to increase the sustainability and cost-efficiency of advanced biofuel production. The 2003 EU Biofuel Directive stimulated these positive expectations and positive technology lessons reinforced them even more. One example of such positive lessons was the adaptation of the biorefinery concept from bioenergy research. Other examples were fuel-specific advances, such as the realization of cellulose ethanol at the lab scale, and further development of the gasification processes needed to make FT-diesel and biocrude from household waste. However, at the end of this period, selected scientists and industries raised doubts about their ability to realize advanced biofuel processes as quickly and as cheaply as promised. This went in parallel with decisions to put planned projects on hold, such as Nedalco's cellulose ethanol plant, the retirement of the New Leaf biosulphurol plant and the AEB HTU plant, as well as the withdrawal of FT-diesel investments in Choren by Shell. Hence, the experiments did not meet the vision and previously high expectations.

Despite reduced expectations at the end of the period, the advanced biofuel actors realised bench scale and pilot plants for both cellulose ethanol and SNG production alongside the existing HTU pilot. Nonetheless, the technology processes remained too immature for further scale-up and thus retained the status of R&D niches.

5.2. A BRIDGING BIOFUEL DISCOURSE, 2003-2010

Unlike the previous periods, which presented a division between conventional biofuel development and other, bioenergy or advanced biofuel discourse developments, this period (2003-2010) showed a different discourse development pattern. The conventional and advanced biofuel discourses that polarized the previous period came together in a bridging biofuel discourse at the initial stage of this period. By the end of the period, an anti-biofuel discourse challenged this bridging discourse.

The discourse developments in this period suggest that I should start this section with an overview of contextual developments. I then describe the bridging biofuel discourse and the anti-biofuel discourse. The section closes with analysis.

5.2.1. Contextual developments

In international developments, the issue of fuel dependency gains a more central position in the debate in this period compared to the previous period. This was partly due to the oil price, which started to rise explosively after President Bush declared war on Iraq in 2003. As indicated by Figure 10, the crude oil price peaked in mid-2008, followed by a steep decline. The average nominal oil price in mid-2008 was equal to that of the oil crisis in 1979. While the previous periods focused on the depletion of oil, the rapid increase in the oil price from 2003 resulted in a more general focus on oil substitution.

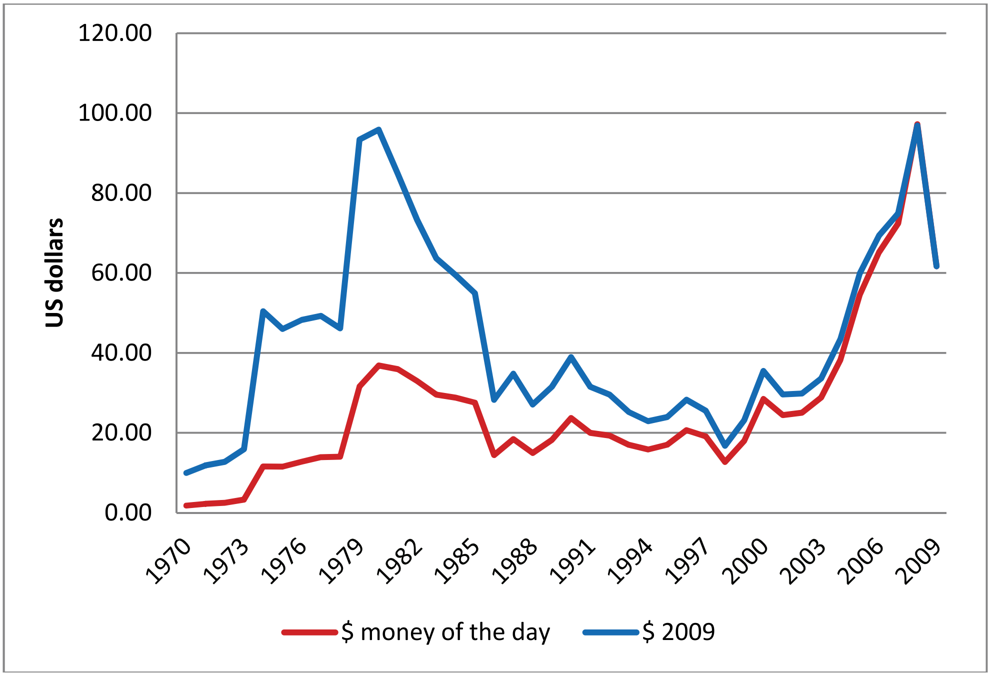

Figure 10: Average annual crude oil price per barrel in US dollars, 1970-2009
Source: BP, Brent dated.

The EU Biofuel Directive was introduced in March 2003. What started out as a mandatory biofuel implementation target became an indicative target in the final directive (EC, 2003a). This was due to objections to a mandatory policy from the majority of the EU member states (Van Thuijl et al., 2003). To facilitate implementation of the Biofuel Directive, an additional directive was issued in October 2003, which allowed member states to give a general biofuel tax exemption of six years or longer (EC, 2003b). While only Germany and Sweden had reached the indicative target of 2 per cent by 2005, implementation of the Biofuel Directive sped up the development of biofuels in Europe in general. The EU estimated the overall biofuel market share to be 1 per cent in 2005, which was double the market share in 2003. While the EU still saw CO_2 reduction as the central motive for biofuel implementation, increasing oil prices led to increased arguments in favour of biofuels as means to reduce fuel dependency. A new round of policy documents[48] led to the promotion of a binding target of a 10 per cent market share for biofuel by 2020 (European Commission, 2007a). As a result of an international anti-biofuel discourse that gained ground in 2007, the idea of biofuel as the ideal solution for reducing CO_2 in the transport sector was challenged and the Commission withdrew its plan for an obligatory biofuel implementation target in July 2008 (Harrison, 2008). A revised directive was ready by 2009 (EC, 2009) in which the focus on biofuels had shifted to renewable fuels in general, which were to meet the 10 per cent target for 2020. In order to avoid supporting environmentally harmful fuels, the directive set out sustainability criteria and advanced fuel options (also biofuels) were stimulated (EC, 2009).

The Dutch first-generation biofuel discourse profited from the urgency created by the growing oil substitution discourse and the EU biofuel discourse, since only the first-generation options were ready for short-term implementation. The first-generation discourse gained attention through the bridging biofuel discourse outlined below. However, the growing anti-biofuel discourse at the end of this period challenged the first-generation biofuels.

5.2.2. Bridging (conventional) first- and (advanced) second-generation biofuels

Despite official announcement of the Biofuel Directive in 2001 and the many international debates that followed, in the Netherlands preparations for the implementation of the directive only began in 2003. A variety of activities were undertaken at the policy level to gain information on how to meet the new EU demands, which also showed a shift in argumentation towards greater acceptance of first-generation biofuels.

The Ministry of Housing, Spatial Planning and the Environment prepared a policy proposal for the government on the implementation of EU policy. The Ministry asked the GAVE programme to invite different market parties and public officials to a workshop to get their opinions on which policy instrument to use for biofuel implementation. At the workshop in January 2003, 35 private sector representatives were present, including oil companies and other interest groups. Representatives of all the relevant ministries (Ministry of Housing, Spatial Planning and the Environment, Traffic and Waterways, Economic Affairs and Finance) attended. Three policy instruments for biofuel implementation were discussed: mandatory targets, covenants and voluntary market introduction. From this workshop, it became clear that the ministries favoured mandatory implementation on condition that there was a sufficient supply of biomass to meet the target and that biofuels did not become too expensive. By contrast, the private sector was clearly for voluntary targets combined with tax exemptions. The option of covenants had less priority among the participants (GAVE, 2003g).

[48] The Biomass Action Plan in December 2005, the Biofuels strategy in February 2006 and the Energy Green Paper of March 2006 highlighted the need to set legally binding targets for biofuels, since biofuel was seen as the only credible alternative to fossil fuel in the transport sector (EC, 2007a).

By taking a position on short-term biofuel implementation, the government radically changed from an antagonistic position towards first-generation biofuel implementation to a more positive and cooperative position. This was probably a result of the increased pressure of the biofuel discourse mobilized at the EU level. Moreover, the preference for mandatory targets indicates that the government did not want to invest in biofuel development, or at least not the large-scale funding that tax exemptions implied. Hence, support for an obligation does rule out the possibility that a certain hesitance towards first-generation biofuels remained. That the private sector preferred biofuel tax exemptions instead of biofuel implementation obligations was no surprise, given their economic motives, particularly when it comes to a product that is still uncompetitive.

As well as the debate on the policy implementation instruments, there were many debates and reports on the quality of biofuels following the Biofuel Directive. The most prominent study was a 'Fact finding study' by the Ecofys consultants Van den Broek et al. (2003), commissioned by Novem on behalf of the Ministry of Housing, Spatial Planning and the Environment, Ministry of Economic Affairs and Ministry of Transport, Public Works and Water Management . In cooperation with a commission with representatives of the private sector, environmental organizations and ministries, the Ecofys consultants evaluated the potential for the Netherlands to meet the EU biofuel targets. The consultants concluded that there was sufficient local biomass to reach the 2005 target, but that imports would be needed to reach the 2010 target. Furthermore, there were no technical or legal bottlenecks to reaching the 2005 target. An additional bottleneck was that the mature, first-generation fuels were very expensive compared to second-generation fuels. Among the second-generation options cellulose ethanol was seen as somewhat cheaper compared to its conventional alternative, while Fischer Tropsch was seen as a very cheap option in the long term. Certification was the preferred instrument for creating incentives in the market, due to the fit with free market mechanisms and the potential to connect them to sustainability standards (Van den Broek et al., 2003). Given that the study was partly based on information from a commission representing both private and public interests, the conclusions are likely to have been shared more generally in society.

In addition to the fact-finding study, Novem was given the task of reassessing the potential of first-generation biofuels and cellulose ethanol. The reason behind this initiative was that 'there are indications that improvements have been taking place at the level of environmental technology and economy in these fuels' (GAVE, 2003a, translation by the author). The quote refers to A.D. Little's (1999) evaluation of various biofuel options. This evaluation had been set up in preparation for the GAVE programme and had been limited by the criteria for 80 per cent GHG emission reductions set by the government, meaning that the potential of first-generation options was not investigated properly (GAVE, 2003a). The Novem reassessment indicated a new era in which the conventional biofuel coalition had much more power to affect policy.

The Novem reassessment took the form of two studies. The first study, on conventional biofuels, Novem assigned to Den Uil from ECN in cooperation with authors from the Agrotechnological Research Institute, ATO, Nedalco and the Product Board for Margarine, Fats and Oils (MVO). Den Uil et al. (2003) concluded that the estimated GHG emission reductions from conventional biofuel were reasonable, but far from the 80% criteria set for the GAVE programme. Rapeseed biodiesel delivered 52-61% GHG emission reductions and wheat ethanol 41-61%. Moreover, the price per tonne of CO_2 emission reductions for conventional biofuels was slightly lower than in the Ecofys study. Den Uil argued for the use of waste biomass in biofuel production and saw the use of waste streams as particularly promising for biodiesel production. As referred to in the previous period, this opportunity was a result of new regulations on animal feed that had left various by-products unexploited. With regard to the EU's biofuel implementation targets, Den Uil et. al (2003) argued, like Van den Broek et al., that the 2 per cent biofuel target set for 2005 could be reached easily using domestic biomass, while the 5.57 per cent target by 2010 was more difficult. In line with the quote below, Den Uil et al. highlighted that implementing first-generation fuels was a necessity not only in order to reach the EU biofuel targets, but also for environmental reasons and as a potential stepping-stone to second-generation fuels:

> [. . .] it is important to note that the conventional bio-transportation fuels will play a major role in the transition from petroleum based to biomass based transportation fuels. Development of markets and supporting mechanisms will be required before the introduction of the more favourable long-term options is feasible. The European directive on bio-transportation fuels will be the driver behind this development. Furthermore, the conventional bio-transportation fuels represent the only possibility to fulfil the guidelines drafted by the EU. (Den Uil et al., 2003: 7)

Den Uil was not the first to use the biofuel stepping stone argument. As reported in the previous section, Van Thuijl (2002) used it in a public report. Both Den Uil and Van Thuijl worked at the ECN research centre. Moreover, the positive position towards first-generation biofuels, biodiesel in particular, is not surprising given the interests of selected authors of the report, such as MVO.

To conclude, in the studies that followed in the wake of the Biofuel Directive, Ecofys (Van den Broek et al., 2003) and ECN (Den Uil et al., 2003; Van Zessen et al., 2003) continued to report on the shortcomings of first-generation fuels, in particular the high costs, as well as the benefits of second-generation biofuels. However, unlike the previous period, all the studies dealing with conventional biofuels agree that first-generation fuels can and will be implemented. Van den Broek and Den Uil were generally positive about the local potential to reach the indicative target of 2 per cent by 2005 using first-generation fuels. Den Uil was one of the few actors who, together with Van Thuijl (2002), argued that first-generation fuels could serve as a stepping stone for the second generation. Hence, these studies indicate that first-generation fuel implementation was not solely seen as an obligation set by the EU, but also as something that could contribute to the development of more sustainable fuel alternatives.

The public authorities were not the only parties to commission studies to investigate whether and how the Biofuel Directive could be implemented. Other stakeholders, representing the interests of specific actor coalitions, commissioned studies and were more radical in their statements. One example was a study by Van der Voort (2003) at a research and business unit focusing on agriculture, sponsored by the Ministry of Agriculture, Nature and Food Quality. Based on the positive experience from Germany, where biodiesel was almost competitive with fossil diesel and market demand was continually growing, Van der Voort argued that rapeseed cultivation in the Netherlands had great potential. As in the German case, however, it would be necessary for the Dutch government to provide subsidies to cover the start-up costs and a long-term and general tax exemption to keep the process going. Van der Voort argued that this support was a means to support not only the economy of the agro-industry, but also the environment (Van der Voort, 2003). This indicates that the farmers' interests in conventional biofuel development were still strong, and that biofuels were still deeply embedded in the farmer livelihood discourse. However, Van der Voort made it clear that this was also for the benefit of the environment, which indicates that subsidies to biofuels in order to support farmers alone were still not generally acceptable.

In addition to the agrarians, Vereniging Nederlandse Petroleum Industrie (VNPI), the Dutch society of the petrochemical industry, was a large interest group that contributed to the debate by commissioning the research consultant CE Delft to carry out a study. In this study, Kampman et al. (2003) compared first-generation biofuels (biodiesel and bio-ethanol) with three biomass electricity routes (biomass co-combustion in coal centrals, as a substitute for fuel oil in refineries and as substitute for natural gas in other energy centrals). The conclusion was that the biomass electricity route should be preferred to transport fuels. According to Kampman et al., co-combustion to produce electricity was the most promising route, three to eight times more cost-efficient than biofuel for the transport sector. Each hectare of biomass for co-combustion could cut three to ten times more CO_2 than biodiesel and 2 to 2.5 times more than ethanol. Even from a long-term perspective biofuels would not become more cost-efficient compared to bioenergy. Hence, if there was still an interest in biofuel, Kampman et al. advised waiting for the introduction of more cost-efficient and environmentally friendly biofuels, such as FT diesel, methanol or HTU-based fuels, once they matured(ibid.). From these statements, it is clear that the VNPI supported the biomass to energy discourse and the second-generation discourse only. Second-generation fuel technologies, such as HTU and FT diesel, were closer to the fossil fuel process than to conventional biofuel technologies.

To sum up, the reports presented by the agrarian lobby and the VPNI indicate that not everyone supported the bridging discourse, but continued to support either the first- or the second-generation biofuel discourse.

In mid-2004, the EU member states were asked to report to the EU on how they planned to meet the biofuel implementation targets of the Biofuels Directive. Despite the possibility that the 2005 target might be met, according to various reports commissioned by Novem, the government chose not to comply with the 2005 target. This was expressed by the Ministry of Housing, Spatial planning and the Environment (VROM, 2004) in a policy memorandum on Traffic Emissions, which outlines ways in which traffic can become quieter, cleaner and more economical. The memorandum stated that the government would set an indicative target of 2% biofuels for 2006 and provide a financial stimulus for biofuel implementation from January 2006. According to the policy document, the reason for not starting the financial stimulus earlier to meet the 2% biofuel target by 2005, as outlined in the EU directive, was the limited time available to set up the necessary financial programme and for industry to prepare for large-scale biofuel implementation. Although biofuels were promoted, the policy memorandum advised avoiding a lock-in to first-generation biofuels, since they were considered very expensive and to have limited environmental potential in comparison to second-generation fuels. Nevertheless, by introducing first-generation fuels it was argued that the CO_2 emission reduction could start earlier and that a market could be created that could facilitate and speed up the introduction of second-generation fuels. To stimulate this policy, CO_2 reduction criteria were to be set out for biofuels. The plan was to start with low CO_2 reduction criteria to allow for first-generation fuel implementation. The criteria would become stricter over time to stimulate the development and implementation of second-generation fuels. The long-term policy plan, aimed at 2030, was to reduce the CO_2 emissions of the transport sector by 40-60%. In addition, the memorandum suggested increased financial stimulation for R&D on the biofuels that deliver the highest CO_2 reduction. To be able to judge the environmental quality of the different biofuels, a certification system with a set of sustainability criteria (related to biodiversity, CO_2, competition with food production, etc.) was suggested (VROM, 2004). This indicates that the bridging biofuel discourse suggested by ECN researchers (Van Thuijl, 2002; Den Uil et al., 2003) had been adopted by the government.

However, not everyone agreed with the government policy memorandum, and the stepping-stone biofuel policy it implied. There were mixed reactions, as a selection of four stakeholder reactions presented below shows. First, the interest groups from the vehicle sector – the RAI Association, an organization for producers and importers of road vehicles, and Bovag, a branch organization for vehicle and mobility entrepreneurs – was positive about the new government policy, especially the decision to stimulate novel technology development (GAVE, 2004d). This indicates a preference for second-generation fuels and an acceptance of the new bridging biofuel discourse in the vehicle sector. Second, in contrast to the vehicle interest groups, the environmental organization Milieudefensie was negative. According to the GAVE newsletter (GAVE, 2004d), the environmental organization argued that this policy would not manage to limit greenhouse gas emissions. It relied too much on the promise of new technology to resolve the emissions problem, while neglecting the real problem – the expanding transport sector that led to a continuous growth in emissions (GAVE, 2004d). The criticism of second-generation biofuels by the environmental organization indicates a trend change. Earlier criticism of first-generation biofuels alone, which appeared at the EU level, was widened to include second-generation fuels. Third, according to Van Wijland (2004a), the actors closely involved in first-generation biofuel development, such as the Foundation Platform Bio-Energy (PBE), were extremely disappointed by the government's decision to postpone biofuel stimulus and implementation. According to PBE, this decision was surprising considering that most neighbouring countries had applied a general tax exemption already. Furthermore, it argued that the delay would leave the Netherlands lagging even further behind on European biofuel development. The PBE saw the decision as a missed opportunity for the Dutch economy, in particular the industrial and agrarian sectors (Van Wijland, 2004a). In this way, the PBE linked conventional biofuels to a general discourse on economic growth. The fourth stakeholder was Van den Heuvel[49] from Senter Novem, responsible for the GAVE programme. Unlike the PBE, he argued that the Netherlands was not lagging behind the majority of EU member states in the implementation of biofuels. He said that many countries were still trying to figure out how to stimulate the use of biofuels in order to meet the targets in the EU Directive. Only a few countries, such as Spain, Germany and France, were at the forefront of biofuel production. The lack of fiscal measures, such as a general tax exemption in the Netherlands compared to countries leading on biofuel production was due to differences in aims, according to Van den Heuvel. He argued that these leading countries subsidized fast implementation of biofuels from energy crops to safeguard farmers' livelihoods and the environment (Van Wijland, 2004b):

> In the Netherlands the focus is more on the environmental effect. We take more time to select [a biofuel] based on that criteria and to find the best solution' (Van den Heuvel cited in Van Wijland, 2004b, translation by the author).

In reaction to the European Commission's request that member states should report on how they were going to meet the demands of the Biofuel Directive, the Dutch government answered that it would not be able to reach the 2005 indicative target of 2% biofuel implementation. Instead, the implementation target was to be set for 2006. The reason given for late implementation of the 2% target was twofold. First, there was no Dutch potential for producing biofuels from biomass since there were no production facilities for biofuels that would enable such large-scale production. Second, before implementation, the Dutch government wished to carry out research to be able to formulate sustainability criteria.

[49] In this period the organization Novem merged with Senter, which explains the new name Senter Novem.

By means of these criteria the government could direct development towards more sustainable, second-generation, fuels and avoid lock-in of less sustainable options (GAVE, 2004c). However, in March 2005 the Netherlands and 18 other member states received a warning from the EU for not reporting on measures taken to implement the Biofuel Directive (EC, 2005). This indicates that there was a lot of political pressure on the Netherlands to meet the targets in the Biofuel Directive, despite its indicative character. The fact that obligatory targets were at the planning stage at the EU level may have contributed to such an aggressive approach.

In parallel with the Dutch in response to the EU Biofuel Directive, the GAVE programme changed its objectives from those of a subsidy programme for second-generation biofuels to a programme that could assist the government and related stakeholders to meet the demands of the Biofuels Directive (Tweede Kamer, 2005a). According to Gigler and Van den Heuvel (2004), the reason for the change in the GAVE programme was primarily uncertainty among investors caused by limited funds for demonstration projects. In the third tender process, administered by the GAVE programme, only € 5 million was allocated for such projects. Hence, like so many biofuel projects, the failure of the GAVE programme was blamed on limited government funds for development and implementation. In addition, the change in objectives was yet another case of the legitimizing effect of the EU Biofuel Directive on conventional biofuels in the Netherlands.

While the GAVE programme failed to implement second-generation biofuel technologies, the vision for long-term sustainable solutions for the transport sector remained. According to the policy memorandum on Traffic Emissions, the Netherlands should implement conventional biofuels but avoid a conventional biofuel lock-in by stimulating more environmentally efficient biofuels, such as advanced biofuels and hydrogen. The main policy activities in support of second-generation biofuels in this period were the Energy Transition policy and the Energy Research Subsidy (Energie Onderzoek Subsidie, EOS).

The government integrated the Energy Transition model, developed in the previous period, into the energy policy of this period. Its aim was to create a transition towards a sustainable energy supply. A transition agenda was set up with various themes that were considered to need extra attention. For each theme, relevant public and private stakeholders were attracted to increase collaboration and action in the field. From an early stage, the theme Biomass was particularly interesting for the development of biofuel applications. It was a popular theme, which attracted a large number of stakeholders and resulted in many workshops (EZ, 2004). The result was a Biomass vision document, *Visie op Biomassa: De Rol van Biomassa in de Nederlandse Energievoorziening, 2040*. This document concluded that biomass could be the basis for 30% of the energy market – for fuel, heat and electricity – and provide 20-45% of the raw material for the chemical sector in the Netherlands in 2040. It was argued that the know-how of Dutch industry, in the fields of chemistry and agriculture, could create potential synergies that would be profitable for the Dutch knowledge economy. Nevertheless, it was pointed out that the sustainable use of biomass – limiting GHG emissions, avoiding competition with food products and protecting biodiversity – was a prerequisite for a positive result (EZ, 2003). All this indicates a preference for second-generation biofuels and an attempt to link up with both the general discourse on regional development and economic growth and the environmental discourse. According to Gigler (2004), the biofuels promoted by stakeholders within the Biomass group were all second-generation fuel technologies, such as pyrolysis oil, cellulose ethanol, HTU, and bio-syngas-based routes such as FT-diesel (ibid.). After a reorganization, the Biomass theme was replaced by other themes, such as Sustainable Mobility and Green Gas (SenterNovem, 2007c). In this way the biofuel development trajectories were spread over different themes, and there were related working groups. The groups 'Driving on natural gas and biogas', 'Driving on E85/FFV' and 'Clean buses' stimulated related biofuel R&D and field experiments (SenterNovem, 2006a). Despite the general preference for second-generation biofuels in the early years of the Energy Transition policy, the stimulation activities in 2006 and 2007 for both first- and second-generation fuels seem to indicate conformity with the bridging biofuel discourse.

To gather stakeholders for platforms to stimulate institutional and technological change leading to sustainable energy development, the Energy Research Subsidy (EOS) was a subsidy programme that provided financial support for individual energy technology projects. The supported projects could take many forms, from information diffusion and R&D to demonstration projects. The focus was renewable energy, in which biofuel technologies and applications were included. The aim of EOS was to contribute to sustainability, with regard to the environment, economic efficiency and security of supply. After a preparatory period that started in 2001, EOS programme activities started in 2004. Different themes and sub-programmes were defined within EOS, which fitted short-term as well as long-term sustainable energy goals (SenterNovem, 2004; Kimman & Soeriowardojo, 2009). In this sense, EOS resembled the goals set for the Energy Transition. However, the EOS programme developed independently from the Energy Transition. It was in later years that their activities were increasingly connected (Macaré, 2006; SenterNovem, 2004). That the new energy policy and subsidy programme developed in parallel, but independent from each other, demonstrates that the energy policy process is not a rational and straightforward one. The policy process is particularly complex and a variety of actors with different interests and contextual settings come into play.

A programme that supported second-generation fuels exclusively was the subsidy programme for Innovative Biofuels for the Transport sector (Innovatieve biobrandstoffen voor transport) (Van Gelder & Kroes, 2008). More on this, and other support for second-generation biofuels, is outlined below.

Returning to short-term policy, the policy memorandum on Traffic Emissions published in 2004 gave a positive signal to biofuel promoters by announcing that financial stimulus would come about in 2006. Nevertheless, the memorandum did not make clear what type of financial support would be given and for how long.

The first-generation lobby went into action to stress the need for a general tax exemption for biofuels. According to the `Biofuel Fact book`, published in June 2004 by De Vries et al. (2004) commissioned by the organization of agricultural commodity boards (Hoofdproductschap Akkerbouw, HPA) and the Rabobank , the Netherlands was well suited to the production of biofuels due to its high concentration of agribusiness that produce suitable by-products. In addition, the authors saw the Dutch petrochemical industry as a potential facilitator of successful biofuel implementation (De Vries et al. 2004). The report was handed to the Minister of Economic Affairs, Brinkhorst, who responded that concrete measures with regard to the stimulation of biofuels would be announced in March 2005 (GAVE, 2004g). The Platform Bio-ethanol, in which central agricultural actors and producers related to starch-, sugar- and cellulose-based ethanol participated,[50] initiated a second lobbying initiative. The platform urged parliament to implement the EU Biofuel Directive and in particular the related directive allowing for an exemption of mineral oil tax on biofuels as soon as possible. The argument was that other member states, such as Germany, were about to

[50] The actors in the platform were: Hoofdproductschap Akkerbouw, Nedalco, Vereniging voor de Aardappel Verwerkende Industrie (Vavi), LTO Nederland, Cerestar/Cargill, Acebe, Suiker Unie and CNV. The platform was part of the Energy Transition.

implement the general tax exemption. Only by mirroring developments in other EU member states could a European level playing field be created. In particular, a long-term tax exemption for biofuels was requested. This was argued to be in the interests of Dutch industry, its competitiveness internationally, and the Dutch economy and society in general (GAVE, 2004g).

As reported in the previous period, biodiesel and bio-oil advocates had gained temporal tax exemptions and started to lobby for a general biofuel tax exemption in 2002. Due to the vague promises made in the bill on Traffic Emissions and pressure from the public, a new policy proposition emerged from parliament in late 2004. In this proposal, it was argued that a general tax exemption must be given by 2006 at the latest. Like the response of Minister Brinkhorst at Economic Affairs, State Secretary Van Geel of the Ministry of Environment replied that the policy memorandum of the spring of 2005 would outline details of the tax exemption. Van Geel promised to meet the request of parliament to financially support the start-up of selected projects in the field of biofuel before 2006 (GAVE, 2004i). Nevertheless, once spring arrived, there were no policy announcements with regard to biofuel support.

Eventually, in the autumn of 2005, in the policy memorandum containing the national budget for 2006, the government communicated how biofuel implementation would be stimulated. The stimulation programme would be through a general tax exemption on biofuels for 2006 only, which would cost € 70 million. The one-year tax exemption would aid and prepare the fuel sector for a Dutch mandatory target of 2% biofuel use in the transport sector by January 2007. The target was to be increased incrementally to reach the EU indicative target of 5.75% in 2010. In addition to the one-year tax exemption for conventional biofuels, a subsidy scheme would be put in place to stimulate the development and implementation of particularly ‘novel and sustainable fuel options’, meaning second-generation biofuels. Contrary to the policy memorandum on Traffic Emissions, this memorandum did not include pure biofuels as a means to reach the 2% target. The argument for supporting mixes only was to reach a larger group of vehicle owners, since no adjustments to engines would be necessary (Tweede Kamer, 2005b: 20-21, 63; GAVE, 2005h).

Once again, the decision of the government led to diverse reactions from the public. One reaction came from Nedalco, which argued that a tax exemption for one year would support neither innovation nor the production of biofuels in the Netherlands. Investments were still too costly and were not likely to be recovered due to the inability of Dutch companies to compete internationally, where tax exemptions were given for several years (GAVE, 2005d). Since 2002, Nedalco had repeatedly announced attempts to set up a first-generation ethanol production plant, but had not succeeded due to lack of sufficient economic support (GAVE, 2004c; Suurs & Hekkert, 2005a). Moreover, in 2004 Nedalco and its partners had successfully patented a fungus that could contribute to the process of cellulose ethanol production. According to Weissman at Nedalco, this technology could be implemented in ethanol production by 2010, with sufficient government support (GAVE, 2004f).

> We will start with a small-scale experiment and later a test factory may follow. This all depends on the decision of the Dutch government to stimulate ethanol of not. If stimulation is given we can compete with gasoline, otherwise we will be forced to sell our patent to the Americans. (Weissman cited in GAVE, 2004f)

Another biofuel actor, Aberson at Solar Oil Systems, was upset that PVO was not included in the biofuel tax exemption plans in the policy memorandum (GAVE, 2005d). On this point, the government policy memorandum was in line with the EU Directive on

Mineral Oil, which dictated that PVO, unlike other biofuels, should fall under the definition of mineral oil and thus not gain a tax exemption (Bijlsma, 2003d). As outlined in the previous section, many PVO actors had already gained tax exemptions until 2010. However, this restriction on PVO would prevent new projects from gaining tax exemptions. Finally, according to the GAVE newsletter (GAVE, 2005d), the environmental organization the Netherlands Society for Nature and Environment (Stichting Natuur en Milieu) reacted to the policy note on tax exemptions by arguing that general tax exemptions for all biofuels was wrong. According to the environmental organization, only biofuels with high environmental gains should gain support, not the 'dirty' ones – referring to palm oil and rapeseed oil (GAVE, 2005d).

Despite the variety of reactions, by the first-generation coalition arguing that the support was far too limited for successful biofuel development or by the second-generation coalition arguing that first-generation fuels should not be supported, the biofuel obligation was accepted by the oil distribution companies. Shell, one of the more critical actors of first-generation fuels, was one of the first to comply with the distribution obligation in 2006 (GAVE, 2007a), and other companies followed thereafter. Nevertheless, the preference for biofuel mixes in fossil fuels outlined in the initial policy memorandum did not form part of the final law. Oil companies could distribute their biofuel share to pure biofuel users as well (SenterNovem, 2010a; Fuelswitch, 2010). However, this was not made clear to the public, and in 2009 there were still references to the law as an obligatory 'biofuel mix' (PBL, 2009).

With regard to actual implementation (see Table 14), it is notable that the distribution of biofuels was higher (2.78%) than the obligatory target (2%) set by the government for 2007. Moreover, while there is a clear increase after implementation of the 2006 general tax exemption and the biofuel obligation from 2007 onwards, 2008 shows the first decline. The radically varying biofuel use in 2008-2010 is surprising but could be partly related to the growing criticism of biofuels and the upcoming anti-biofuel discourse, which is outlined below.

	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Ethanol (million litres)	–	–	–	38	176	218	284	278
Ethanol (% of gasoline energy base)	–	–	–	0.55	2.0	2.47	3.14	3.05
Biodiesel (million litres)	4	4	3	29	286	231	301	121
Biodiesel (% of diesel energy base)	0.05	0.05	0.04	0.35	3.28	2.61	3.61	1.44
Biofuels, total (million litres)	4	4	3	67	463	449	586	399
Biofuels, total (% of gasoline and diesel energy base)	0.03	0.03	0.02	0.43	2.78	2.56	3.42	2.09

Table 14: Consumption of biofuel in the transport sector, pure and blends, 2003-2010
Source: Statistics Netherlands, June 2010

5.2.3. The anti-biofuel discourse

Growing implementation rates were not mirrored by societal support for biofuels, which declined as a result of increased criticism during the latter part of this period. One reason why environmental organizations were critical of PVO, and why the EU Directive on mineral oil and the Dutch government did not include PVO in the general biofuel tax exemption, may have been its doubtful or low level of environmental benefits.

According to Croezen and Kampman (2005) at the research and consultancy bureau CE Delft, the environmental performance of PVO was low. SenterNovem commissioned this report because recent biofuel evaluation reports such as Van den Broek et al. (2003) had not included PVO. Croezen and Kampman (2005) concluded that PVO would only reduce GHG emissions by 30% compared to diesel, which was low in comparison to Van den Broek et al.'s (2003) estimates on biodiesel (50%) and ethanol (25-45% depending on the feedstock). Moreover, Croezen and Kampman (2005) concluded that the cost of CO_2 reduction by means of PVO was very high. In comparison to estimates of ethanol and biodiesel CO_2 reduction capacity calculated by Van den Broek et al. (2003), the cost per tonne of CO_2 reduced by PVO was almost three times greater.

It is likely that the growing criticism of another vegetable oil, palm oil, which was part of the development of an international anti-biofuel discourse, led to a particularly critical perspective on PVO in the Netherlands. Around the turn of the century, the first negative social and environmental consequences of large-scale production of palm oil in Indonesia were reported internationally by a variety of NGOs, in particular environmental organizations (Milieudefensie, 2005; Milieudefensie, 2008). Meanwhile, the bioenergy discourse grew and the Dutch government subsidized domestic energy companies for using biomass by means of a subsidy programme that aimed to increase the environmental quality of Dutch electricity production, MEP (Milieukwaliteit Elektriciteitsproductie) (SenterNovem, 2009b). The forerunner in environmental applications among Dutch energy companies was Essent. Essent was also one of the few companies that started large-scale production of electricity from palm oil under a green label. After the negative international publications on palm oil, the environmental organization Friends of the Earth Netherlands organized a massive anti-palm oil campaign against Essent in 2005-2006. In this campaign, the core arguments against the cultivation of palm oil for Dutch bioenergy were deforestation, the draining of peat moors and the violation of work and land rights in the South (Milieudefensie, 2006). Other environmental organizations, such as the Netherlands Society for Nature and Environment, joined the lobby against palm oil. At a later stage, development cooperation agencies, such as Novib and Both Ends, also decided to join the lobby against the use of biomass and biofuel chains that might have negative environmental and societal impacts. The solution proposed was the implementation of a number of criteria which biomass for fuels or electricity would have to meet to be allowed on the Dutch market. Examples of the criteria are: no competition with local food supply, no destruction of special ecosystems such as rain forests and savannahs, no conflicts with regard to the land rights of the local population and no excessive or unprofessional use of artificial fertilizers (GAVE, 2005i). In 2006, Friends of the Earth sued Essent for a misleading commercial, based on Essent labelling palm oil electricity as green. As a result, Essent stopped using palm oil feedstock. After the lawsuit, the State Secretary of the Ministry of Environment, Van Geel, publicly apologized for the fact that millions in public funds, MEP subsidies, had been used for the production of electricity from palm oil (Milieudefensie, 2006). In the same year, the MEP subsidy was ended, despite the fact that funds were reserved for the subsidy programme until 2013. The reason given by the Minister of Economic Affairs was that the Netherlands would reach the sustainability targets for 2010 without the financial support of the MEP (SenterNovem, 2009b). However, it is likely that the scandal over palm oil contributed to this decision.

After the scandal over palm oil in the bioenergy sector, actors are likely to have become more sensitive to problems in similar sectors, such as the production of biofuels for transport. An additional crisis, increasing food prices and food shortages in the South, helped to strengthen the anti-biofuel discourse and directed criticism against biofuels in the transport sector (e.g. Aan de Burgh, 2007). In particular, the increasing price of corn flour in Mexico gained a lot of attention in the media. According to the food industry, increasing food prices were due to the increased production of biofuels. For instance, the industry blamed the high price of Mexican corn on the increased production of corn ethanol in the USA. The biofuel industries, however, argued that increasing food prices were a result of many factors, such as increasing oil prices, failing harvests and changing food consumption especially in China where growing welfare had resulted in increased meat consumption dependent on increasing cultivation of crops for animal feed (Aan de Burgh, 2007).

An anti-biofuel feeling was not only growing in the Netherlands or among environmental and development cooperation organizations – a wider global anti-biofuel discourse was appearing, reflected in reports from international organizations like the IMF (Forbes, 2007), the World Bank (Mitchell, 2008), the OECD (Clark, 2007) and the Gallagher Commission (2008) in the UK. These reports contributed to the idea that the ability of biofuels to prevent climate change and increase sustainability was limited and that biofuels posed a threat to the future supply of cheap food. Scientists contributed to this discourse by various publications, some of the most debated articles were that of Cruetzen et al. (2007) and two articles in the journal *Science* by Searchinger et al. (2008) and Fargione et al. (2008). The OECD and environmental organizations enhanced the negative image of biofuels as competing with foods by referring to them as ‘agro-fuels’ (Clark, 2007). This was a catchy name that was picked up by the media and thus aided the spread of a negative biofuel image to the wider public.

Meanwhile, the EU announced that it planned to introduce binding targets for biofuel implementation. In preparation for a future energy policy, the EU published a communication paper, the Renewable Energy Roadmap, in January 2007 (EC, 2007b), which presented a target for a CO_2 emissions reduction of 20% by 2020. To reach this target, an obligatory target of at least 10% biofuel implementation was set for the transport sector. In addition to CO_2 reductions, the EC used independence from politically unstable oil producing countries as an important motive for biofuel implementation. A third motive was the economic gain from decentralized and domestic biofuel/bioenergy production (ibid). Hence, once again, the EU embedded its arguments for biofuel development in current environmental, oil substitution and economic development discourses. The communication (EC, 2007b) indicated that the Commission was not content with the low level of compliance by member states with the indicative targets. The indicative target for 2005 was set at 2%, but member states had only achieved 1%. However, the EU did not only blame the member states, but the various barriers caused by the high cost of biofuels, the lack of standards and regulations to facilitate implementation and the antagonism of particular fuel distributors too. The EU announced that it intended to eliminate the legal barriers at least. It also wanted to safeguard sustainable production of biofuels by stimulating second-generation biofuel production, preventing the deforestation of rainforests and investigating the potential use of certification schemes (EC, 2007b). The arguments of the emerging anti-biofuel discourse could explain part of the slow pace of biofuel implementation. However, comparing policy processes at the EU and the national levels, the national level reflected increasingly critical perspectives regarding the environmental qualities of biofuels. In this respect, the anti-biofuel discourse seems to have influenced Dutch biofuel policy at an early stage.

The environmental qualities of biofuels had been the subject of debate in the Netherlands for a long time. In the 2004 bill on Traffic Emissions (VROM, 2004), the government was already arguing that sustainability criteria should be formulated to stimulate the development of more sustainable and long-term biofuel options, which indicated a continuing preference for highly advanced second-generation biofuel options. With the debate on palm oil and related debates on the competition between biofuels and food, the issue of formulating criteria for biofuels rose up the political agenda. As a result of the growing anti-biofuel discourse, the criteria were no longer a matter of environmental sustainability alone. Other issues, such as local livelihoods (food and working conditions), were added to the definition of a sustainable biofuel option. In addition, the debate showed a broadening of environmental concerns. An example of the latter was the move away from a single focus on GHG (primarily CO_2) emissions in the North to a more global perspective including GHG emissions in the South, biodiversity and other ecological factors along the whole biofuel chain, from production to use. According to the scientist, Jaqueline Cramer (2006), it was the high expectations for biomass as a source of sustainable energy, on the one hand, and the risks of large-scale biomass production, on the other, which stimulated the appointment of a commission to investigate and design sustainability criteria for biomass in 2006. The Cramer Commission, named after its chair who in February 2007 became the Minister of the Environment, aimed to formulate criteria not only for the Netherlands, but also for the broader international level, since the Commission expected a great part of the biomass to come from abroad. In the short term, the criteria were to aid bioenergy policy and the biofuel implementation policy outlined in 2005. In brief, the criteria concerned biomass production and processing in the field of energy, fuel or chemical production. The criteria followed issues of concern such as greenhouse gases, competition with food and other local resources, biodiversity, welfare, well-being and the environment. These criteria were first and foremost meant for the period 2007-2011, but were expected to continue in a modified form as a follow-up for new scientific investigations on sustainability in the future (Cramer, 2006). The commission published its final report in February 2007 (Cramer, 2007). The government's response was positive and the Ministry of Development Cooperation and the Minister of Environment (Cramer) saw opportunities by concluding that sustainable production of bio-energy and biofuels could offer major opportunities for developing countries (Biopact Bioenergy news, 2007). Similar thoughts were also expressed by Cramer one year later:

> Together with my colleague Koenders [Minister of Development Cooperation], I am busy setting up field trials for sustainable energy production by local farmers for the local population in developing countries like Indonesia and Mozambique. It is not only about biofuels. Instead of dependency on fossil fuels, favourable natural conditions in developing countries at this moment create opportunities for sustainable energy forms, also for small farmers and land users. (Cramer, 2008b, translation by the author)

The government did not implement the Cramer criteria in 2007 as planned. The formulation and implementation of the criteria were more difficult than first anticipated. For instance, leaders and representatives of countries in the South were invited to the Netherlands to give their views. The representatives from Indonesia and Brazil, in particular, argued that more severe criteria would not help safeguard environment or people's welfare and well-being in the South. In addition, to implement the criteria in the form of certificates, international agreements would have to be set up, which was particularly difficult in relation to existing World Trade Organization agreements (Jumelet, 2007).

Although many barriers prevented the implementation of sustainability criteria, the government did not give up. One example of this was the way in which the sustainability criteria and biomass were embedded in current and future energy policy by the publication of a vision of a 'bio-based economy' by a majority of the Dutch Ministries (LNV, VROM, EZ, BuZa, & V&W, 2007). A bio-based economy implies that non-food biomass will be used to a great extent in a variety of sectors, thereby reducing the use of fossil feedstock for the production of energy, heat, transport fuels, chemicals, and so on. The main aims of the bio-based economy were to create a transition to a sustainable energy supply and reduce the use of mineral oil (LNV et al., 2007). The latter shows parallels with the Agrification policy of the 1980s, aiming to create new non-food markets. However it was increasingly influenced by means of a more recent trend, that of biorefinery, which put a greater focus on efficiency and sustainability. According to the Dutch Ministries (LNV et al., 2007), the bio-based economy would use the implementation of sustainable criteria as one means to ensure sustainability. With regard to biofuels, the preference went to second-generation fuels due to their focus on non-edible biomass that would not compete with foods and the higher efficiency of these fuels. A vision for second-generation biofuels set out in this document was market introduction by 2012-2017. To stimulate advanced biofuels, the government set up an R&D fund of € 60 million for the period 2007-2010 (LNV et al., 2007). A biofuel subsidy programme 'Innovative Biofuels for the Transport Sector' (Innovatieve biobrandstoffen voor transport) emanated from this fund. In addition to the stimulation of second-generation fuels, this aimed to prevent first-generation lock-in (Van Gelder & Kroes, 2008).

In addition, to push the agenda for sustainable criteria, the Dutch Government set out to gain more support for the criteria at the international level. A parallel development trajectory was already taking place in the UK, so the UK and the Netherlands started collaborating with the ambition of influencing EU renewable energy policy. Germany also joined the coalition. In early 2008, this resulted in a proposal for a Renewable Energy Directive (RED) in which sustainability criteria would be included (VROM, 2008). At the national level, Cramer and her colleague Koenders, the Minister of Development Cooperation, advised the government on how a sustainable policy for the period 2008-2011 would stimulate sustainable biomass for biofuel and bioenergy production at the international level. In addition, a follow-up to the Cramer Commission was set up, the Corbij Commission (2009), to explore how to deal with the sustainability dimension when implementing the RED. The result was various subsidy programmes related to research and development of renewable biomass production and use, as well as the implementation of the EU sustainability criteria in Dutch biofuel policy in 2011 (GAVE, 2011).

The growing anti-biofuel discourse, that biofuel production leads to deforestation and higher food prices, was also leading to criticism of the EU's biofuel policy. In particular, the plan to introduce an obligatory 10% biofuel implementation target for 2020 had become highly controversial. The EU had introduced the plan with great enthusiasm in January 2007. By July 2008, however, the EU had cancelled the plan due to the widespread belief that it was morally highly questionable. Various EU ministers distanced themselves from the plan. One example was the French Ecology Minister, Jean-Louis Borloo, who said that people had misinterpreted the target to mean 10 % from biofuels alone. He argued that the EU had still to make clear that the obligation could include green electricity or hydrogen used in vehicles (Harrison, 2008). The arguments of Borloo were set out in the RED, announced in late 2008 (EU, 2008) and agreed in April 2009 (EC, 2009). The directive dictated that 10% of transport fuels should be renewable by 2020, implying that the focus should no longer be on biofuels alone. The directive recognized electricity and hydrogen as additional renewable means to meet the target. Moreover, the directive set out sustainability criteria for renewable fuels in order to avoid support for less efficient and environmentally harmful fuels. Finally, advanced fuel options in particular were stimulated. Transport biofuels based on waste, residues, non-food cellulose materials and ligno-cellulose counted as double for the implementation target set by the EU, and the energy used in electric vehicles counted 2.5 times more than that of conventional biofuels (EC, 2009).

The RED entered into force in 2010 at the EU level. In the Netherlands, however, the double counting of biofuels from waste, residues or ligno cellulose was implemented in late 2009 by means of a special scheme for Double Counting Biofuels (Regeling dubbeltelling betere biobrandstoffen) after pressure from parliament (GAVE, 2011).

Hence, the anti-biofuel discourse brought about great changes at both the national and the EU level. However, the sustainable criteria in the EU directive were less severe compared to the criteria set out by the Cramer Commission in 2007. In addition, support for second-generation biofuels was granted at an earlier stage in the Netherlands than at the EU level. The sustainability criteria and the stimulus for second-generation fuels could indicate either that the effect of the anti-biofuel discourse was stronger in the Netherlands at this point or simply that the reaction to the discourse was faster at the national level due to less complex and lengthy policy processes.

In the Netherlands the growing anti-biofuel discourse not only contributed to the development of sustainability criteria, but also led to a reduction in the Dutch biofuel implementation targets set out in late 2005 for the period 2007-2010. In October 2008, the national biofuel target set for 2009 was adjusted from 4.5% to 3.75% and the target for 2010 was adjusted from 5.75% to 4%. Hence, the government reversed its previous intention to reach the targets set out in the Biofuel Directive. The government defended its policy change by arguing that the Netherlands would still reach its Kyoto targets. In particular, the review published by the Gallagher Commission in the UK was a big influence on this policy decision (Cramer, 2008a). The Gallagher Commission (2008) stated that a fast implementation of biofuels would not result in increased sustainability because practitioners could not yet trace the origin of biomass/biofuels. A trustworthy certification system would be required to achieve traceability and put the sustainability criteria into practice (ibid.).

Support for the conventional biofuel discourse was declining with increasing uncertainty about its positive effects. The reduction in implementation targets and shifting biofuel consumption from 2008 to 2010 (see Table 14) were responses to the weaker conventional biofuel discourse. However, this development trajectory might not only be due to the anti-biofuel lobby. The high feedstock prices which acted as a trigger for the anti-biofuel discourse and the economic crisis of 2008 may also have contributed to the stabilization of biofuel consumption.

The actions of conventional biofuel actors might explain why conventional biofuels vanished from the market. Conventional biofuel actors applied new strategies to avoid the growing anti-biofuel discourse. In particular, actors in the agrarian sector and entrepreneurs argued against the accusations. According to Rosendaal, who started the biodiesel production company Rosendaal Energy B.V., the belief that biofuels carried sole responsibility for increasing food prices was not true. According to Rosendaal, the higher food prices were due to failing harvests, low investment in agriculture in recent years and high oil prices, which increased the production costs of the agricultural sector (van der Meer, 2009). Another strategy, used by many of the PVO and biodiesel actors producing biodiesel from waste oils and animal fats, was to claim a fit with the second-generation biofuel discourse. According to the director of Sobel, Sjors Beerendonk, biodiesel from animal fats was like any second-generation biodiesel – it did not compete with food production and did not add to environmental problems, such as reduced biodiversity or CO_2 emissions, like some conventional biofuels did (Engwerda, 2007). That these fuels fit into the Dutch scheme for double counting biofuels, implemented in 2009, indicates that they gained a status similar to that of second-generation biofuels and thus increased acceptance in the second-generation biofuel discourse.

Even though the government reduced the biofuel implementation targets, it continued to support biofuels – albeit in a more careful manner within added restrictions and sustainability criteria. In addition to support for low fuel mixes through the obligation on fuel distributors, the government implemented a new subsidy programme to support the construction of alternative fuel stations, Tankstations Alternatieve Brandstoffen (TAB), for high and pure bio-, and gaseous fuels. The Minister of Transport put out the first tender in May 2008. It had a budget of € 1.8 million for the construction of ethanol and natural gas fuel stations (V&W, 2008). National and regional authorities financed and administered the second tender process in 2009, in which € 4.1 million was available for ethanol (E85), high blend biodiesel (30% biodiesel, B30) and pure natural or bio-gas refuelling stations (SenterNovem, 2010b). The first tender process in particular was very profitable for ethanol developments, which received funds for the construction of 69 ethanol fuel stations (BEST, 2009). The argument behind the TAB programme was to speed up the implementation of biofuels in order to comply with the government's 2004 policy memorandum on traffic emissions, which set out to reduce emissions from traffic and transport (V&W, 2008). Hence, the continued government support for biofuels was one result of the strong CO_2 reduction discourse.

In fact, increased debate on the climate meant that the CO_2 reduction discourse was increased in strength after 2005. One example was the documentary by Davis Guggenheim, 'An inconvenient truth', which premiered in 2006. In this documentary, the former US vice president Al Gore warned about the risks of climate change and the need to act. The film was a box office success, which created general awareness and a debate about climate change. The many awards given to the film, not least the Nobel Peace Prize given to Al Gore and the IPCC in 2007, indicated the growing relevance of climate change. Another activity that increased attention on climate change was the publication of the Stern Report in the autumn of 2006. The first comprehensive review of the economics of climate change, it concluded that it would be much cheaper to minimize climate change by early GHG reduction activities than to go on as usual and pay to fix the damage in the future (Stern, 2006).

The impact of the anti-biofuel discourse on the second-generation biofuel discourse is less clear. In some cases it seems to have stimulated the development of the second-generation discourse, for example when the EU gave more support to second-generation fuels once the criticism of agro-fuels gained ground (EC, 2007b; Jumelet, 2007). Moreover, environmental organizations were milder in their criticism of second-generation fuels compared to first-generation fuels. However, they saw an equal need to apply environmental criteria to second- as well as first-generation fuels (van der Meer, 2009; De Provinciale Milieufederaties & Stichting Natuur en Milieu, 2008). For the EU and the environmental organizations, the main argument for defending second-generation fuels was that they were not competing with food.

Nevertheless, we should not forget that the new EU Renewable Energy Directive (EC, 2009) promoted not only second-generation biofuels, but also electric and hydrogen propelled vehicles, which were given proportionately more support. The EU altered its previous focus on biofuels as the future transport fuel by including other renewable fuels in the policy. This may reflect declining support for biofuels at the EU policy level. According to Jumelet (2007), the scientific community, which had been the main actor promoting second-generation biofuels in the Netherlands, became increasingly hesitant about second-generation fuels in the final years of this period. In addition, the former Dutch Prime Minister, Ruud Lubbers, who was the current chairperson of the Rotterdam Climate Initiative, did not believe in the potential of second-generation biofuels, arguing that they were 'false promises' (ibid.). An event that supported Jumelet's thesis was the decision to end the only second-generation development programme: Innovative Biofuels for the Transport Sector in 2008 (Van Gelder & Kroes, 2008). According to Van Gelder and Kroes (2008), the programme was paused for evaluation and, depending on the outcome, in 2009-2010 a decision would be made on continuing it (ibid.). There is, however, no sign that the second-generation biofuel programme was continued. Although funding was severely limited, some second-generation biofuel support continued. According to Van der Meer (2009), another subsidy programme started in 2008 with the aim of assisting the development of a bio-based economy until 2012. Despite having energy innovation as its primary focus, it did support some second-generation alternatives.

The slowdown in second generation discourse development can also be recognized at the level of the fuel technology. The leading actor in the field of cellulose ethanol, the Canadian ethanol company Iogen, which had been collaborating with Shell since 2002, has become very quiet with regard to reports of technological process. Moreover, Nedalco, which had been highly visible in the media as a result of its patent, lowered their profile and put their cellulose project on hold in mid-2008. According to an employee at Nedalco, the pause in activities was due to changing market conditions. First, rising feedstock prices affected the waste feedstock such as wheat bran that Nedalco was experimenting with. Second, cheap Brazilian ethanol was increasingly dominating the European market, which made it difficult for other ethanol producers to survive. Third, changing government regulations and objectives with regard to biofuel implementation targets and sustainability criteria created uncertainty (van der Meer, 2009). The last point in particular was a consequence of the anti-biofuel discourse, which in addition to some positive effects also had negative effects on the development of second-generation fuels.

Interest in FT-diesel, the most promising option at the turn of the century, seems to have faded in recent years. While the technology process had been developed at the laboratory scale, the industry had also become increasingly hesitant, even though a promising collaboration had been set up between Shell and the Dutch gasification company Choren in 2005 (Jumelet, 2007; van der Meer, 2009). Industrial actors agreed that FT-diesel and other second-generation options were more expensive than conventional biofuel. Brunesse at Shell had hopes that FT-diesel would become competitive with conventional biodiesel, but both Rosendaal at the biodiesel producer Rosendaal Energy B.V. and Breman at Sasol strongly questioned the future economics of FT-diesel. Rosendaal backed up his argument by referring to the IEA report, 'World Energy Outlook 2006', which showed that the price of FT-diesel would drop, but that it would remain more expensive than conventional biodiesel in 2030. Breman agreed with the conclusion of the IEA report and added that he could not foresee any technological innovations or ideas on reducing the production costs of FT-diesel (van der Meer, 2009). That Shell saw promise in the FT-diesel option was logical because it had invested heavily in the technology through its cooperation with the German company, Choren. Sasol, on the other hand, had long been focusing on FT-diesel from coal, which was an old established technology. According to Van der Meer (2009), Sasol was not the only one interested in coal FT-diesel. Shell and other industrial actors and scientists had increased their interest in coal in recent years, particularly the potential for producing clean synthetic fuels (such as FT-diesel) or energy from coal by means of carbon capture and storage. Another promise was the combination of coal and biomass as feedstock for FT-diesel (van der Meer, 2009). The latter development might be linked to the oil substitution discourse, which in this period was propelled by increasing oil prices and increasing concern about dependency on politically unstable countries. However, while less obvious, a broader vision and 'clean coal' alternatives could become more attractive now that the anti-biofuel discourse is growing.

Another effect of the growing anti-biofuel discourse was the creation of more uncertainty around the sustainability of biofuel options. The trust that was put in second-generation biofuel options at the turn of the century was less apparent in the Netherlands after 2007. However, like first-generation fuels, support was still given to second-generation fuels in the form of double counting in relation to the renewable (bio)fuel implementation targets. However, the increased support for other renewable fuel alternatives, such as hydrogen and electric propulsion, showed an interest in what scientists had earlier dubbed 'third-generation biofuels'. The involvement of other fuels indicates a move away from the biofuel-oriented bridging scenario towards a bridging technology discourse, and from first-generation biofuels to renewable fuels in general.

5.2.4. Discourse analysis, 2003-2010

2003-2010					
General policy	**Level**	**Year**	**Type**	**Size**	**Description**
Biofuel Directive	EU	2003	regulation		Indicative target of 2% biofuel implementation by 2005 and 5.75% by 2010
Fuel tax Directive	EU	2003	regulation		Permit to give general biofuel tax exemption.
GAVE support programme	Government	2003-	information dissemination		Assist the government and stakeholders in reaching the EU targets.
Energy Transition	Government	2004-	information & collaboration		Novel policy approach to stimulate sustainable energy for 2010 and beyond, stimulates primarily advanced biofuels
Proposal Biofuel Directive	EU	2007	regulation proposal		Obligatory target of 10% biofuel implementation by 2020.
Biofuel obligation	Government	2007-	regulation		2% of all transport fuels biofuels by 2007. Percentage should be increased successively to 5.75% in 2010. Targets withdrawn in 2008, replaced by RED in 2010.
Cramer Commission	Government	2007			Definition of sustainability criteria for bio- energy, chemicals and fuels. Has not been fully implemented.
Biofuel obligation revised	Government	2008	regulation		Target for 2009 from 4.5% to 3.75% and 2010 from 5.75% to 4%
Renewable Energy Directive (RED)	EU	2009	regulation		Target of 10% renewable fuels by 2020. Prescribing sustainable criteria and double counting of biofuels based on waste and non-food materials. Proposal 2008, implemented 2009.
Double Counting Biofuels	Government	2009	regulation		National scheme based on EU RED recommendations.
Sustainable criteria	Government	2011	regulation		Implementation of RED sustainable criteria in Dutch biofuel policy.
Advanced biofuels	**Level**	**Year**	**Type**	**Size**	**Description**
GAVE R&D programme	Government	-2003	R&D	M	Programme tailor-made for gaseous and liquid biofuels.
EET R&D programme	Government	1996-2003	R&D	M	Economy, Ecology and Technology R&D programme. Supports mainly ethanol, projects; ran until 2009.
EOS	Government	2004-	R&D	M	Energy Research Stimulation programme aims to support the development of sustainable energy supply.
Innovative Biofuels programme	Government	2006-2008	R&D	M	Programme for development and implementation of particularly novel and sustainable fuel options for the transport sector. € 60 million budget was reserved for 2006-2010, but the programme was ceased in 2008.

Conventional biofuels	Level	Year	Type	Size	Description
Biodiesel Friesland	Government	2002-2006	tax exemption	M	3 years for 77 boats, 1 year for 35 boats benefitting from general biofuel tax exemption
Biodiesel Friesland	Government	2005-		M	35 boats
PVO Aberson	Government	2002-2010	tax exemption	M	8 years for North Netherlands oil mill and PVO vehicle market
PVO OPEK	Government	2002-2010	tax exemption	S	8-year tax exemption for OPEK oil mill and market in the period 2002-2010, but production did not start until 2004 and use was small scale
PVO Carnola	Government, Province, EU	2005-2010	tax exemption	M	5 year tax exemption for Carnola Cooperation oil mill
General tax exemption	Government	2006	tax exemption	M	1 year general tax exemption (€ 70 million) for all biofuels excluding PVO.
Subsidy for alternative fuel stations (TAB)	Government, municipalities	2008-2009	Subsidy	S	€ 5.9 million for construction of alternative fuel stations. Approximately 70 E85 pumps.

Table 15: Conventional and advanced biofuel policy developments, 2003-2010

Conventional biofuels (first generation)

Biofuel	Discourse	Mobilization/ impact of wider discourses, events and policies	Discourse coalition	Target audience	Key activities, strategies	Resulting space/policy creation or disruption
Biodiesel, ethanol and PVO production, pure and blend use.	Discourse similar to the previous period, but focused increasingly on CO_2 emission reductions; had national and regional economic development including farmers' well-being as a secondary goal. Conventional biofuel seen as the only environmental solution in the short term that could serve as a bridge to more advanced solutions.	Embedding was sought in global environmental discourse as well as regional development discourse. All biofuels were seen as means to reach EU indicative biofuel implementation targets set in 2003	Farmers' organizations return as a central actor together with the alcohol industry, while entrepreneurs and local authorities are less prominent in this period. Initial collaboration is increasingly reduced at end of period.	Government and wider public as audience to prove that biofuel is indeed a good alternative despite criticism towards the end of the period.	Lobbying for general tax exemption and against imports competing with domestic production. The lobbying was mainly expressed in media and research reports. A main strategy to increase reference to the Netherlands as lagging behind other EU member states in biofuel implementation and reference of waste-based conventional fuels as second-generation fuels.	EU policy to create increased legitimacy for conventional fuels. Main policy a biofuel implementation obligation for oil distribution companies is set out together with a one-year tax exemption for ethanol and biodiesel. Stimulates low blend market expansion. Implementation of sustainable criteria at the end of period limits space for conventional biofuel development.

The discourse was similar to the previous period, but focused increasingly on environmental issues and emission reductions of CO_2 with a secondary focus on economic development, which was widened from regional development to national economic growth. The CO_2 focus led to embedding in the increasingly CO_2-oriented environmental discourse. However, the setting of EU indicative targets for biofuel implementation and the failure to realize second-generation fuel development within the GAVE programme also stimulated increased embedding in the environmental discourse. Additional efforts to gain policy support from a government that had prioritized advanced biofuels saw the return of the discourse argument that the Netherlands was lagging behind biofuel implementation internationally. The discourse presented conventional biofuel as the only environmental option for the transport sector in the short term, and a technology that could serve as a bridge to more advanced and efficient environmental fuel solutions in the future. According to den Uil et al. (2003): 'conventional bio-transportation fuels will play a major role in the transition from petroleum based to biomass based transportation fuels. Development of markets and supporting mechanisms will be required before the introduction of the more favourable long-term options is feasible'. At the end of the period, increased criticism of conventional fuels appeared from an anti-biofuel discourse criticizing conventional biofuels in particular for competing with foods. This resulted in the setting out of sustainability criteria, and in limits to the range of conventional biofuels supported by the EU and the government. Based on this development, biofuel coalition actors distanced themselves from competition with food and blamed increasing food prices on failed harvests and high oil prices. Some embraced sustainable criteria, which sometimes led to the promotion of biofuel from new sources of waste.

Compared to the previous period, farmers' organizations and the alcohol industry regained a central position in the coalition, while previously leading entrepreneurs and local authorities were pushed to the background. This indicates a broader coalition with more powerful actors which are likely to have contributed to discourse growth. The coalition actors used reports, the media and the policy arena to gain increased legitimacy for their discourse. Many strategies were used to gain increased legitimacy in the changing discourse context. A strategy to gain support from a government prioritizing advanced biofuel solutions was, first, to stress that the Netherlands was lagging behind in biofuel implementation and, second, to promote conventional fuels as a bridging technology to more advanced options. The latter was partly made possible by increased acceptance of conventional biofuels by advanced biofuel actors. A response to the growing anti-biofuel discourse at the end of the period was the promotion of particularly sustainable production routes, such as waste-based biofuels.

As a result of the coalition's activities and the publication of the EU Biofuel Directive, the conventional biofuel discourse gained stability. However, instead of giving long-term financial support, the Dutch Government chose to set an obligatory implementation target for fuel distributors that increased incrementally. This policy benefited low blend biofuel use in fossil fuel while support for domestic production, high blend and pure biofuel use remained at the margins. At the end of the period, the anti-biofuel discourse severely challenged the legitimacy of conventional biofuels and related government and EU incentives.

Advanced biofuels (second generation)

Biofuel	Discourse	Mobilization/ impact of wider discourses, events and policies.	Discourse coalition	Target audience	Key activities, strategies	Resulting space/policy creation or disruption
Advanced biofuels	Similar arguments as in the previous period, e.g. high CO_2 reductions, high energy efficiency and relatively low costs in the medium to long term in comparison to conventional biofuels.	Embedding was sought in the global environmental discourse, economic development (and innovation) discourse at the national and development cooperation levels	Scientists and research institutes driving the coalition, as well as government institutes (Senter Novem/GAVE)	Government, general public	Lobbying for increased funds to achieve pilots and commercialization. Use of media and scientific publications. The main strategy was acceptance of first-generation fuels as a bridging technology (especially if waste-based) once EU demanded short term biofuel implementation.	R&D funds given continuously, but support is slightly reduced towards the end of the period due to increased criticism and promise of other fuel alternatives.

In this period, the discourse still presented second-generation biofuels as the best fuel solution for the transport sector in the medium- to long-term, despite the failure to realize fuel pilots within the GAVE programme. Similar arguments as in the previous period were repeated, e.g. higher CO_2 reductions, energy efficiency and relatively low costs compared to conventional biofuels in the medium- to long-term. As a result of the increased urgency of short-term biofuel implementation after the publication of the EU Biofuel Directive, a new discourse element was a more positive attitude towards first-generation fuels. The use of first-generation fuels as a bridging technology to facilitate second-generation fuel implementation with the prerequisite that first-generation lock-in was avoided became increasingly accepted. By the end of this period, the discourse was again distancing itself from conventional biofuels by stressing that advanced biofuels were to be preferred since they, unlike many conventional biofuel techniques, did not compete with foods. The latter reflected an attempt to embed in the new anti-biofuel discourse, which was highly critical of conventional crop-based biofuels and resulted in national policy that benefitted waste-based biofuels. Proof of successful embedding in the anti-biofuel discourse was increased support for advanced biofuel implementation as a result of the double counting government measure. However, the anti-biofuel discourse also created increased uncertainty with regard to the sustainability of advanced biofuels, which had a negative influence on discourse stability.

Research institutes and scientists remained the core of the advanced biofuel coalition in this period, while government actors were supportive but less active in lobbying for second-generation fuels after the failure of the GAVE programme – although they still expressed a preference for advanced biofuel solutions. The coalition mainly played out its lobbying activities in the media with support from scientific publications and reports. The main strategies were an increased acceptance of first-generation fuels as a bridging technology, once the EU demanded short-term biofuel implementation which could not be provided with advanced biofuels. Increasing anti-biofuel sentiments meant that acceptance was later limited to waste-based conventional biofuels alone.

Despite the failure to fulfil the promise of the GAVE programme, the variety and number of actors supporting the advanced biofuel discourse increased at the initial stages with continuous R&D funding as a result (see Table 15). Towards the end of the period, competition from alternative fuel discourses gained increased support from the anti-biofuel discourse. The implementation of sustainability criteria and the new EU Renewable Energy Directive led to a slight decrease in support for advanced biofuels.

Anti- biofuel discourse, early 2000s onwards

Biofuel	**Discourse**	**Mobilization/ impact of wider discourses, events and policies.**	**Discourse coalition**	**Target audience**	**Key activities, strategies**	**Resulting space/ policy creation or disruption**
Conventional biofuels, but later also advanced fuels	Against energy cropping for bioenergy and biofuels for causing negative environmental effects in developing countries and limited ability to reduce global emission. Later, competition with foods (fuel vs. food debate) and negative socio-economic effects in the South were included in the critique.	Embedding was sought in the global environmental discourse.	Central players were NGOs, (environmental and development cooperation organizations at the international and national levels). At a later stage scientists and international organizations, such as the OECD, the World Bank and the IMF, and developing countries joined.	Government, general public	This discourse was debated in the media, scientific work and in local, national and EU political arenas. One of the main strategies was reference to conventional biofuels as 'agro-fuels' to stress their competition with food.	The discourse reduced space for biofuel development by reducing the legitimacy of these fuels, contributing to harsh sustainability criteria and the withdrawal of obligatory biofuel implementation targets in 2008. Similar effects were also visible at the EU policy level.

In the early 1990s, the bioenergy discourse served as a forerunner for the anti-biofuel discourse. It was critical of the negative environmental effects of large-scale, EU-subsidized agricultural practices in biofuel production. In the early 2000s, a separate anti-biofuel discourse emerged, which had a more global perspective compared to the bioenergy discourse. It criticized both energy cropping for bioenergy and biofuels for causing negative effects on biodiversity in developing countries and their limited ability to reduce global emission such as CO_2. Some years later, the discourse included the negative socio-economic effects of energy cropping in the South, such as food shortages and high food prices. Like the various biofuel discourses, the anti-biofuel discourse gained embedding in the environmental discourse.

The central players in the anti-biofuel coalition were NGOs, both environmental organizations and development cooperation organizations at the international and national levels. Soon, scientists and international organizations, such as the OECD, the World Bank and the IMF, and developing countries joined the lobby. The coalition lobbied at the international and local levels by means of scientific publications, reports, media coverage and active participation in various policy arenas. Among the main strategic moves were the 'food versus fuel debate' and reference to conventional biofuels as 'agro fuels' to stress their reliance on crops and competition with food. The actors had particularly large political influence. The number of actors supporting the discourse increased successively, particularly at the end of the period, as a result of increasing food prices, which fuelled the food-versus-fuel argument. The power of the actors and their number contributed to an influential discourse.

Although the conventional biofuel discourse tried to fend off the criticism of low CO_2 emission reduction and negative socio-economic effects, the anti-biofuel discourse gained in power during this period. The power of the anti-biofuel discourse was visible in the development of sustainability criteria for biofuels, which started in the Netherlands, and the adjustment of the national and EU policy focus from biofuels to renewable fuel implementation.

5.3. CONCLUSIONS: BIOFUEL DEVELOPMENT, 2003-2010

This section draws conclusions on the biofuel developments in the period 2003-2010, first, from an SNM perspective and, second, from a discourse perspective.

5.3.1. Conclusions: biofuel niche developments

Conventional biofuels advanced during this period, thanks partly to the increased expectations that followed the publication of the EU Biofuel Directive and partly to the realization that advanced biofuels would not be commercial in the short term. While government support for conventional biofuels was more consistent than in previous periods, it was still delayed and limited to a one-year tax exemption and biofuel implementation obligation. This mainly created business opportunities for large trading and fuel processing companies around Rotterdam harbour, resulting in low blend market niches.

Despite government incentives for low blend biofuels, positive expectations, good leadership and growing network collaboration continued to work in favour of domestic production and the use of high blend and pure conventional biofuels. This contributed to an ethanol FFV market niche of about 5000 vehicles and related infrastructure. Biodiesel and PVO also showed initial growth, but there are no statistics about the number of vehicles running, which indicates the relative weakness of these niches in comparison to ethanol. However, high fuel prices and the limitation of filling stations to biodiesel blends indicate a declining market at the end of the period. In the case of PVO, the expiry of tax exemptions in 2011 contributed to additional market decline. High feedstock prices and competition with imported biofuels limited the expansion of domestic production.

Like conventional biofuels, positive expectations and networks expanded in this period, but advanced fuel networks did not show the same degree of actor commitment and collaboration as conventional fuel networks. In addition, government funds were limited to R&D alone, which meant that industry had to carry the costs of implementation. Hence, industry turned increasingly to more mature and potentially more lucrative projects abroad. The inability of industry to carry the costs and technology bottlenecks contributed to reduce expectations and impede niche development of advanced biofuel options at the end of this period.

5.3.2. Conclusions: biofuel discourse developments

In this period, the previous polarization between first- and the second-generation fuels was drastically reduced. The EU biofuel lobby in the lead up to the biofuel implementation target gave increased legitimacy to the conventional biofuel discourse. The inability to use advanced biofuels to reach the short-term biofuel implementation targets set by the EU led to the acceptance of a bridging technology solution by the advanced biofuel coalition in which conventional biofuels would serve as a stepping stone to advanced biofuels. Despite the bridging biofuel discourse, the preference for advanced biofuels remained strong. Strong support for advanced biofuels was visible in the government support for temporary first-generation solutions, such as low blends, imports rather than domestic production and pure fuel use such as PVO. That low blends and imports were beneficial for the petrochemical industry in Rotterdam Harbour and the Dutch economy in general is likely to have been a contributory factor in the choice of this policy.

At the end of the period, an international anti-biofuel discourse grew exponentially as a result of high food prices and a coalition actors that had high political influence. The anti-biofuel discourse challenged the first-generation fuels for being environmentally unsustainable, and also causing negative socio-economic effects. Waste-based conventional biofuels and advanced biofuels managed to avoid the harshest criticism. However, there were also negative consequences for the advanced biofuel discourse. Because of the anti-biofuel discourse, advanced biofuel was no longer seen as the fuel of the future, but just one of many potential renewable fuel alternatives.

The result of these discourse developments is a decline in financial support for biofuels, particularly for conventional biofuels. EU and national policy start to pay more attention to a wider variety of renewable alternatives for the transport sector, such as electric vehicles.

PART II: BIOFUEL DEVELOPMENT IN SWEDEN, 1970-2010

6. BACKGROUND TO SWEDISH BIOFUEL DEVELOPMENTS AND IMPLEMENTATION

6.1. INTRODUCTION OF CHAPTERS OUTLINING SWEDISH BIOFUEL DEVELOPMENT

This chapter serves as an introduction to the Swedish case study and analysis. It sets the stage by sketching the context and biofuel-related developments before the 1970s, when modern biofuel development began.

Developments in biofuels that took place between 1970 and 2010 are described in chapters 7 and 8. The period 1970-1997, described in chapter 7, is a biofuel development period when single biofuel experiments develop into different biofuel market niches. The focus is particularly on high blend and pure biofuel use. Initially, the development of alcohol fuel dominates – first methanol and later ethanol. In the second half of the period, biogas and biodiesel complements ethanol development and implementation. The period 1998-2010, described in chapter 8, is a period when biofuel market development and implementation accelerate into a large-scale biofuel market for high blend and pure biofuel use in vehicles as well as low blend use with fossil fuel. This period also sees the maturation of advanced biofuels, resulting in the production of advanced cellulose ethanol and DME.

Chapters 7 and 8 describe the development of different biofuels in the defined period. For each biofuel, two development perspectives are presented. In the first section, I present a niche perspective focused on the innovations and entrepreneurial experiments that contributed to biofuel technology development and implementation (socio-technical configurations). These are analysed using an SNM framework. In the second section, I present a policy perspective focused on the policy processes that contributed to biofuel protection. These are analysed from a discourse perspective. I close each chapter with SNM and discourse conclusions on all the biofuels.

6.2. SETTING THE STAGE FOR SWEDISH BIOFUEL DEVELOPMENTS

This section outlines the various historical developments of relevance to Swedish biofuel development. The focus is on the early experiments with biofuels and related political events in the 20th century, in particular on wood-gas and ethanol which were used as emergency fuels in the First and Second World Wars.

Sweden was neutral in both World Wars, but suffered from fossil fuel shortages due to its lack of domestic petrochemical resources and to trade barriers. These fuel shortages stimulated biofuel market development (Sundin, 2006). The biggest alternative fuel was gas produced from wood, and the second biggest ethanol produced from sulphate lye, a waste product from the paper and pulp industry (SMAB, 1978).

Wood gas was developed in the late nineteenth century as a fuel for stationary engines (Bertilsson, Brandberg, Pilo, Laveskog, and Isaksson, 1986). For vehicle use, wood gas required large gas generators hung on the back of vehicles which produced a gas fed directly into the combustion engine. While wood gas market vanished after 1945, when gasoline prices normalized (SMAB, 1978), it remained the prime emergency fuel from 1914 until the 1980s because it was easy to mobilize in the short term (Bertilsson et al., 1986).

Sulphate ethanol was a by-product that resulted from improved environmental practices in the paper and pulp industry in the early twentieth century. It was also a substitute for chemicals and food alcohols. When used in vehicles, it was usually as a 25% ethanol mix in gasoline. Initially, the temperance movement opposed the use of sulphate ethanol. However, it became increasingly legitimate with the growing scarcity of petrochemicals during the First and Second World Wars (Sundin, 2006). Consequently, ethanol went from being banned to being heavily subsidised by the government (Jordbruksdepartementet, 1980; SMAB, 1978). With the normalization of fuel prices after 1945, ethanol fuel vanished from the vehicle sector (SMAB, 1978). However, sulphate ethanol remained an emergency chemical. For this reason the government subsidised a small production unit until the 1980s, despite the fact that the sulphate process was long outdated as an efficient paper and pulp production technology (Jordbruksdepartementet, 1980).

The cheap oil price, and the idea that it was a much cheaper, easier and cleaner energy source than coal, led to increased oil consumption during the 1950s and 1960s, despite a brief oil shortage as a result of the Suez crisis in 1956 (Kaijser, 2001). It was not until the 1970s that people started to question growing oil consumption, due to the emerging idea of oil as a finite resource which grew with the publication of the Club of Rome report in 1972 and the oil crisis in 1973. At the same time, Volvo started to question the use of wood gas as an emergency fuel, arguing that it was no longer fit for heavy vehicle engine technology which had been closely adjusted to the fuel properties of the oil-based fuels (SMAB, 1978). The increasingly urgent need for an alternative fuel opened up opportunities for biofuel development and implementation.

7. INTRODUCING BIOFUELS TO THE SWEDISH VEHICLE MARKET, 1970-1997

7.1. THE DEVELOPMENT AND FALL OF METHANOL, 1970-1986

This section describes the emergence and fall of methanol fuel in the period 1971-1997. First, I present the development of the methanol niche followed by an SNM analysis. Second, I describe the political processes leading up to the methanol policy followed by a discourse analysis.

7.1.1. Methanol niche development, 1970-1986

The 1973 oil crisis highlighted Sweden's massive dependence on imported oil. In 1970, Sweden used 30 million m^3 of oil, amounting to 70 % of its total energy consumption (Vedung, 2001: 96; Zacchi & Vallander, 2001). Approximately 80 % was used for space heating and 20% in the transport sector (Zacchi & Vallander, 2001). To reduce oil dependency, the government introduced an energy policy of which a new and broad Energy Research Programme was a central part (Statens energiverk, 1984b).

The Energy Research Programme started in 1975. Until the mid-1980s, the programme funded several individual alternative fuel projects that tested different products, conversion techniques and raw materials, i.e. wood, peat and coal. According to Zacchi and Vallander (2001), the gasification of wood to produce methanol dominated alternative fuel activity during this period. The car company Volvo in particular showed a strong preference for methanol and was one of the actors initiating methanol R&D activities.

Volvo started to research the potential of alternative fuels as early as 1971. The reason behind Volvo's research activities was its cooperation with the National Board of Economic Defence (ÖEF) and a re-evaluation of wood gas, the existing emergency fuel in Sweden. In response to the oil crisis of 1973-1974, Volvo set up an official working group on alternative fuels. Its research concluded that the current emergency fuel, wood gas, was no longer fit for the modern turbo-charged diesel engines used by the most crucial transport vehicles (heavy vehicles) in times of crisis (SMAB, 1978; Abrahamson, 1975). Alternative fuel options researched were hydrogen gas, liquid hydrogen, ethanol, methanol and synthetic gasoline. Volvo concluded that methanol was the most promising emergency fuel since the fuel was easy to handle, relatively cheap compared to the alternatives, had potential environmental benefits and could be produced from domestic resources. With regard to environmental benefits, Volvo pointed out that methanol could reduce the need for lead, a toxic ignition improver used in gasoline, and reduce emissions such as nitrogen compounds, carbon oxides (CO) and nitrogen oxides (NO_x). The greatest benefit, however, was the potential to use domestic resources for methanol production, which made it a suitable substitute for oil in times of crisis (Abrahamson, 1975). Examples of domestic resources for methanol production were: limestone in reaction with water, various types of shale and biological matter such as peat, household waste or wood (Abrahamson, 1975; SMAB, 1978). Volvo was not alone in supporting the methanol option; the wider automobile industry and related lobby actors shared Volvo's expectations (Walldén, 1975).

By 1975, Volvo had run methanol experiments with 10 cars of various brands. Most of them were running on a mix of 80% gasoline and 20% methanol without engine modifications. Volvo had also been experimenting with diesel engines, but only with pure methanol since diesel and methanol would not mix. Because methanol would not ignite as well as diesel, Volvo experimented with spark plugs, heat and additives to start the engine. Other methanol-related problems found by Volvo were its low energy content per volume, the risk of separation in mixtures with other fuels or in contact with water, and the fact that methanol was as toxic as gasoline (Abrahamson, 1975).

As a follow-up to these experiments and studies on methanol, the government agreed to cooperate with Volvo in a technical development company, Swedish Methanol Development (Svensk Metanolutveckling AB, SMAB), set up in March 1975. The aim was to investigate and develop: (i) the use of pure methanol and methanol in mixes with fossil fuels; and (ii) the supply and use of methanol under normal conditions and in times of crisis (SMAB, 1978). When SMAB started, the government owned company Beryl Kemi AB owned 60% of its shares. Volvo owned the remaining 40%. This was reflected in the financial investments for the activities of SMAB in the period 1975-78, where the government allocated SEK 14 million through the Energy Research Programme and Volvo SEK 6 million (SMAB, 1978). The Energy Research Programme gave an additional SEK 6 million in financial support for SMAB's activities. Methanol research and field experiments coordinated by SMAB were the main alternative fuel activities funded in the first three-year period of the Energy Research Programme (Johansson, 1980)(see Table 16).

Motor fuel	**Funding in million SEK**
Methanol	75.7
Ethanol[a]	3.5
Synthetic petrol	7.7
Gases	1.0
Not fuel specific	14.5
Total	102.4

Table 16: Funding for alternative fuels by the Energy Research Programme, 1975-1981
Source: (DFE, 1982) see also (Sandén & Jonasson, 2005)
[a] The ethanol research funding started in the fall of 1980.

SMAB's (1978) evaluation of the first three years of research concluded that methanol was the best alternative fuel option. In particular, SMAB promoted a production process based on the gasification of feedstock followed by a synthesis and the use of a 15-20 % methanol mix in gasoline. From an infrastructure perspective, the transition to methanol blends was simple compared to the problems implied by pure methanol. Moreover, while pure methanol would result in fewer emissions compared to blends, methanol blends would still substitute the most toxic element – lead (SMAB, 1978; Johansson, 1980). In addition to the benefits, SMAB identified institutional barriers to the introduction of methanol. In particular, fuel taxes that were set by volume instead of energy content were a problem for methanol, which only had half the energy content of gasoline and so, in effect, was taxed twice as high. A second institutional barrier was the sceptical and restrictive position of oil companies towards methanol fuel. Nevertheless, SMAB believed that the increased competitiveness of methanol would eliminate this problem in the future (SMAB, 1977).

Based on the fear of a second oil-crisis, the government implemented a new energy policy in 1979 (Kignell, 1981). The policy supported a wider variety of alternative fuels. This meant a 50% increase in the RD&D budget for 1979-1981 and a focus on short-term implementation by means of conventional technology and feedstock, aiming at the development of domestic feedstock (wood and peat) technology to reduce oil dependency in the future. The government believed that methanol or other synthetic fuels could be implemented in the 1980s by using imported fossil raw material such as natural gas (Ahlmark & Johansson, 1978: 133-134).

SMAB reorganized to meet the demands of the new policy. In 1979, SMAB replaced its methanol focus with a wider alternative fuel agenda. The government increased its share in SMAB to 90%, represented by the public companies Studsvik Energiteknik AB (80%) and Svenska Petrolium (10%). Volvo's share declined to 10%, which could be an indication of declining interest in alternative fuels. For the period 1979-1981, a budget for the basic activities of SMAB was set at SEK 10 million, of which the government contribution was SEK 8.5 million channelled through the Energy Research Programme (DFE, 1981). To highlight the broader agenda taken on in 1979, the name changed from SMAB to the State Propellant Technology Company (SDAB) in 1981 (SDAB, 1982).

In line with the new government policy stressing short term implementation, SMAB/SDAB initiated a large-scale trial with M15 vehicles in 1979. M15 was a fuel mix containing 15% fossil-based methanol, 83% gasoline and 2% isobuthanol[51] (Johansson, 1980: 13). In the period 1980-1982, 1000 vehicles were running on M15 fuel. These vehicles could refuel at 19 M15 distribution stations spread over Sweden (see Figure 11). As Figure 11 indicates, the project was part of a larger European M15 trial. Hence, in parallel with the trial in Sweden, there were another 1000 M15 vehicles running in Germany supported by 30 distribution locations, and two smaller projects in Norway and Denmark (Bertilsson et al., 1986). Linked to the Swedish methanol trial was the decision to reduce the fuel tax on methanol by 50% per volume in 1980. In this way, the lower energy content of methanol was compensated for and methanol became more competitive. However, one year later, the government added other alcohol fuels to this, which meant that the fuel additive MTBE and ethanol, with far higher energy contents compared to methanol, gained the same tax exemption (Industridepartementet, 1983).

The alternative fuel policy changed radically in 1981 (SDAB, 1982: 16). Quite different from the previous focus on methanol M15 blends, this policy presented an introductory plan for the development of pure fossil-based methanol fuels (M100) and related vehicles operating in fleets. The bill indicated that the ongoing research with M15 and lower blends was to receive continued support to keep options open in case of changes in the international market (Swedish Commission for Oil Substitution, 1982: 3-5; SDAB, 1982: 16). Despite this, in 1982 the M15 trials were ended and only limited support was given to very low blends (Salomonsson, 1983; Bertilsson et al., 1986). In the 1983 government bill, the focus on M100 became clearer. The government intended to increase the trials with the M100 vehicles incrementally. In the field of research, the plans were to give continued attention to the development of a commercial technology for methanol production based on domestic feedstock (Industridepartementet, 1983).

The general target of the bill was to enhance the options for oil substitution. The government introduced a variety of policy instruments, such as the Oil Substitution Fund financed by a surcharge of SEK 24 per m^3 oil consumed (DFE, 1981: 30). In 1981, the government introduced another surcharge – a special national security tax (särskilda beredskapsavgiften) of SEK 19 per m^3 oil consumed. This financed the Energy Research Programme for the period 1981-1984, a total of SEK 1400 million, which was another dramatic increase in general programme funds by SEK 600 million. The majority of the funds were focused on energy production in general, in particular bioenergy. Of the part of the funds reserved for alternative fuels, propulsion systems and fuel refinement, the budget increased

[51] The reason for mixing isobuthanol into the methanol-gasoline mix is to prevent the methanol from separating from the water in the gasoline, one of the drawbacks of using methanol (Johansson, 1980: 13).

from SEK 76.4 million in 1978-1981[52] to SEK 177 million for 1981-1984. The Alternative Fuel Programme, part of the Energy Research Programme, became more focused on short-term results and commercialization than before (DFE, 1981). This focus was not that surprising considering the high oil price during this period.

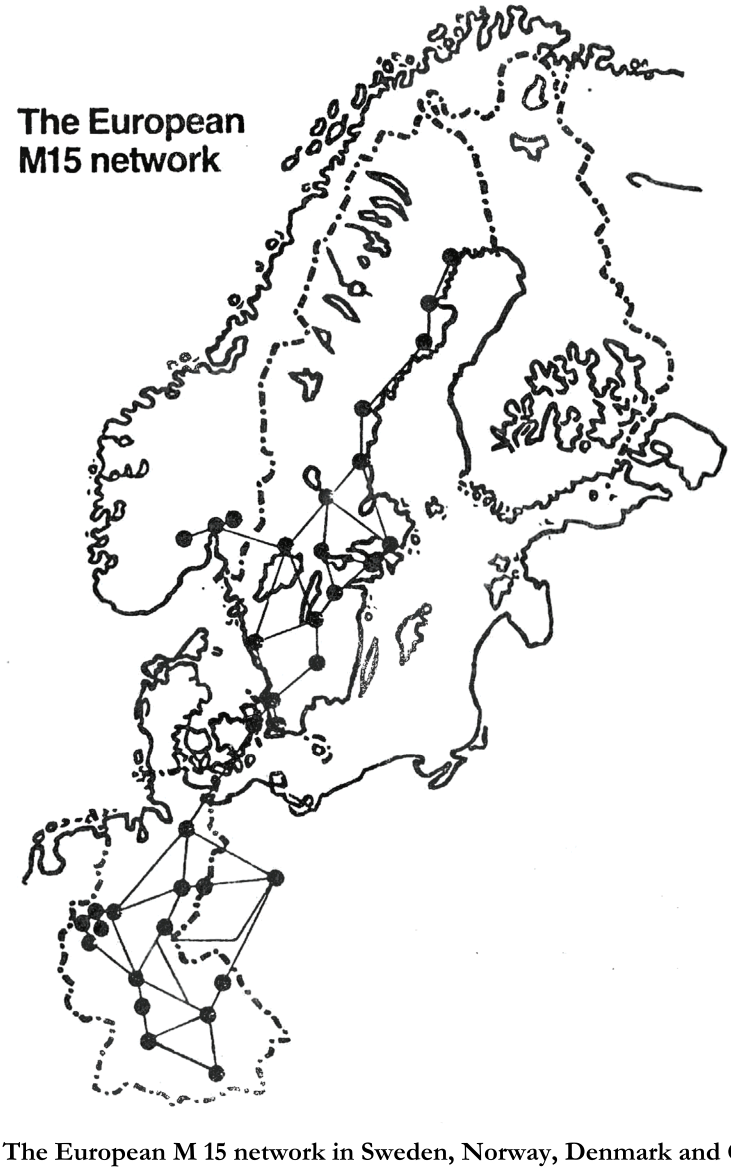

Figure 11: The European M 15 network in Sweden, Norway, Denmark and Germany
Source: (Bertilsson et al., 1986: 42)

52 In the case of the period 1978-81 27.3 million SEK was spent on alternative fuels and propulsion technology. Based on the references above and DFE (1982), additional funding for fuel refinement, etc., is estimated at 49.1 million SEK.

The change in policy towards M100 put an end to the M15 trial with 1000 vehicles and related distribution network, despite the positive end-user evaluation of the first two years (1980-82) of the trial (Salomonsson, 1983; Bertilsson et al., 1986). The evaluation reported no problems in the operation of vehicles running on the M15 mix, provided the recommended engine conversions and services were carried out by the vehicle producers. Moreover, most participants in the trial gave the use of M15 a clear preference over conventional gasoline due to the environmental benefits, which mainly referred to the substitution of lead (Bertilsson et al., 1986). Nevertheless, the arguments of end-users about the working of the technology did not weigh as heavily as the government's arguments regarding the relatively limited potential for oil substitution and environmental gains of M15 use compared to pure methanol use.

In 1980, SDAB, Volvo and AB Greater Stockholm Public Transport initiated a small-scale trial with two diesel buses running on M100. The buses used a two-fuel engine technology developed by Volvo with methanol as the main fuel and diesel to enable ignition.[53] The total cost of the project was SEK 1.18 million. The overall results of the project were positive, although some smaller problems appeared due to contamination of the fuel at the fuel depots of the public transport company. When the field trial ended in 1982, Volvo was given SEK 3 million in subsidies to optimize the two-fuel methanol engine technology.

A second M100 trial was initiated within the M100 implementation programme set out by the government in 1983. It had a budget for the introduction of 200-300 cars and 100 buses running on M100 (Bertilsson et al., 1986). The Swedish Energy Agency and the Swedish National Board for Technical Development (STU) ran the trial. STU contributed the majority of the financing for the project, a total budget of SEK 9.9 million. SDAB and FVV Aerotech[54] acted as project leaders (Statens energiverk, 1986). The project involved 22 cars with Otto (gasoline) engines, of which the majority were Volvos and Saabs. It started in July 1984 and continued until November 1986. Like the diesel engines, engineers modified the Otto engines to facilitate the ignition of methanol. Some of the vehicle engines were equipped with separate ignition systems using gasoline as fuel and some of the vehicles used a mix of 10% lead free gasoline in the methanol fuel to facilitate ignition. Distribution of M100 was available in Göteborg, Stockholm and Östersund (Bertilsson et al., 1986; Statens energiverk, 1986).

In addition to the field trials, bio-based methanol production was also under development. SMAB was the first to suggest a trial on the gasification of wood, peat and household waste for the production of methanol in the town of Bergvik, Hälsingland in the 1970s. However, the Industry Minister did not grant the requested funding since the project was not considered economically viable, even with increasing oil prices in 1979 (Johansson, 1980). In parallel with the debates around Bergvik, new plans and other potential solutions were sought through research on the gasification of domestic raw materials such as biomass and peat (Miljö och Energidepartementet, 1989).

Research on methanol production had been ongoing since 1975 at the Royal Institute of Technology (Kungliga Tekniska Högskolan, KTH) in Stockholm and the Faculty of Engineering at Lund University (Lunds Tekniska Högskola, LTH), funded by subsidies from the Energy Research Programme. At the end of the 1970s, they managed to set up a working gasification process, known as the Mino process. In cooperation with the state-owned

---

[53] A modification to enable the ignition of methanol in diesel engines used abroad is the application of a spark plug (Statens energiverk, 1986).

[54] FVV Aerotech was part of the Swedish Air Force and responsible for the construction and maintenance of military aircraft.

research institute Studsvik Energiteknik AB,[55] a pilot of the Mino process was set up at the Studsvik site with a capacity of 500kg feedstock per hour. It was a fluidized bed reactor in which gasification occurs under pressure at a temperature of 700-800°C. A high-temperature filter and a so called cracker, separating tars and methane, cleaned the gas. In 1984, a study was started to estimate the costs of producing methanol based on the substitute natural gas (SNG) produced in a Mino gasifier (Statens energiverk, 1984a: 47). The network of researchers had planned to set up a demonstration installation that would include the final step of synthesis into methanol, but this was not achieved due to the lack of commercialization potential as oil prices fell (Miljö och Energidepartementet, 1989). The set up of the pilot is likely to have contributed to what Zacchi and Vallander (2001: 136-137, 197) see as a general move of the research activities on gasification from the Royal Institute of Technology (KTH) in Stockholm to the Studsvik institute during this period (ibid.). In addition to the Mino technology, other gasification technologies studied were: the German High Temperature Winkler (HTW) in an international cooperation with Germany and Finland, the Coal Injection Gasification project (CIG) with coal as a feedstock, the Randstad gasification of oil shale, and the coal based plasma technology of SKF Steel company, later known as Chemrec (Statens energiverk, 1984a: 48).

Another potential route for methanol production was the pyrolysis process. Pyrolysis was the conversion of feedstock such as coal, peat or biomass, to a gas, a liquid and a residual slag by means of gasification under pressure in an oxygen-free environment. In Sweden, this technology gained attention in the late 1960s due to its potential to deal with the growing amount of waste (Forsberg, 1972). In addition to dealing with the waste problem, pyrolysis researchers expected the process to deliver basic chemical products. Once the oil crisis was a fact, they saw the pyrolysis liquid as a potential route for the production of methanol to substitute for fossil fuels in the transport sector, and for the production of biogas to substitute for fossil feedstock for energy production. In addition to waste, wood became a promising raw material. Leading pyrolysis researchers such as Lindström at KTH argued for the possibility of using forest feedstock alongside waste to increase fossil oil substitution. In addition, Lindström argued that pyrolysis had great environmental benefits. For instance, he claimed that great sulphur emission reductions could be made by substituting an oil fuelled combined heat and power (CHP) plant with fuels produced from waste by pyrolysis (Hillbom, 1973). The set up of a full-scale pyrolysis plant for energy production from household waste in the early 1970s in the city of Gislaved indicates that expectations for energy production from pyrolysis were particularly high. The government spent approximately SEK 18.5 million on the pilot, but the project failed (Norgren, 1977). The technology development shifted towards faster processes, so-called flash pyrolysis, and additional government funds generated more experiments (Werner, 1978). Despite the problems of achieving the pyrolysis of biomass, continued activity indicates that the promise of pyrolysis technology as a source for fuel, such as methanol, and energy products was held alive throughout this period. The energy authority (Statens energiverk, 1984a) led the participation of Sweden in an international cooperation on pyrolysis within the IEA research project, which indicates that the promise of pyrolysis was shared internationally.

The emphasis on oil substitution in the transport sector, and in the sector of heat and energy production in the big cities, led to a cooperation by various partners interested in the gasification route in 1978. The cooperation included: SMAB, the oil refinery company Nynäs Petrolium, the district heating company Södertörns Fjärrvärme AB, the energy company Sydkraft AB and the Greater Stockholm Energy Board (Storstockholms Energiverk). They

[55] Studsvik Energiteknik AB was previously the nuclear research company AB Atomenergi.

came up with the idea of a gasification installation with a combined production of methanol for vehicles, fuel gas for electricity and heat for district heating generated from the cooling systems of the plant. The location of the plant in Nynäshamn and the Stockholm region as the expected market meant that the project became the Nynäshamn-Stockholm Combined Energy Facility (Energikombinatet Nynäshamn-Stockholm). At the request of the project partners, the National Swedish Board for Energy Source Development (Närlingslivets Energidelegation, NE) granted SEK 650 000 for the feasibility studies necessary for the project proposal. The project partners contributed an additional SEK 1 million. The result was a project proposal and a request to various authorities for organizational and financial support to realize the project. The proposal included references to contemporary reports supporting the argument for large-scale methanol implementation as well as the development of a decentralized coal-based heat and energy plant for the Stockholm area on a short-term basis. According to the project partners, the plant would use fossil feedstock with high sulphur content for which there was little interest on the world market, and which was cheaper than traditional oil products and had the potential to increase Swedish fuel and energy supply security. The plan was to set up experiments with local feedstock technology, based on peat and biomass, once the technology was sufficiently mature. The project partners intended to use local feedstock in case of emergency only, such as trade blockades of fossil feedstock due to political controversies or war. Nevertheless, the partners presented the production process as environmentally benign due to the ability to capture emissions such as sulphur, small particles, heavy metals and hydrocarbon. In addition, the plant would replace the much more polluting practice of oil combustion for energy and heat. It had good economic prospects due to the cheap feedstock and the flexible production process, which enabled adjustment of output according to need, for instance, prioritizing heat and energy production in the winter and fuel in the summer. The approximate production capacity of the plant per year was 700 000 tonnes or approximately 886 million litres of methanol, and 2.5 TWh fuel gas of electricity. The cost of constructing the plant was SEK 2-2.5 billion (Kignell, 1981). The consultancy firm Nycomb Synergetics took over the Nynäshamn gasification project. At the end of the 1980s, it terminated the project due to local public environmental concerns with regard to the use of coal, and harsh competition on the Stockholm heat and power market. However, some of the Nynäshamn competences transferred to Chemrec, a company connected to gasification and energy production in the pulp industry (Sandén & Jonasson, 2005).

Methanol-related gasification experiments ended in the mid-1980s. For the first time since 1975, the government decreased its alternative fuel funding. The alternative fuel budget of the Research, Development and Demonstration (RD&D) programme for the period 1984-85 to 1986-87 was set at SEK 56 million, a decrease in funds with by more than a factor of 10 compared to the previous three-year budget (DFE, 1981; Statens energiverk, 1984a). The government ended all ongoing alternative methanol projects and directed all research on gasification to general energy production. The remaining alternative fuel RD&D funds were limited. According to the Energy authorities responsible for the policy, the increasingly stable and cheap oil price no longer justified continued efforts to develop and implement (bio-based) methanol or other alternative transport fuels. Should methanol become of interest in the future, the authority expected that it would be natural gas-based only (Statens energiverk, 1984a).

According to Brandel (1994), the Nynäshamn gasification project was the last methanol-related project to receive government subsidies in the 1980s. The biomass-based methanol production technology was not sufficiently mature and the fossil-fuel technology was not a sufficient fit with growing environmental concerns (Brandel, 1994). Sandén and Jonasson (2005) agree with Brandel's conclusion and add that the fast decline of the technology was because methanol had not become sufficiently institutionalized in society. The project had identified the lack of vehicle and fuel distribution standards, but nothing was done about it. Moreover, the distribution of methanol did not involve the petrochemical industry, which kept the old fossil fuel regime going. Methanol fuel pumps were rudimentary and temporary, which made them easy to remove. Sandén and Jonasson highlight the swift retirement of the main methanol supporter, SDAB, once funding ceased (ibid.). SDAB's move could be related to the lack of institutionalization of methanol, but also to the fact that government-owned companies were the biggest shareholders in SDAB.

The change in government support from gasification for methanol production to gasification for energy production alone contributed to a move by gasification researchers to the energy field. Some of them started an energy-oriented consultancy firm, Ecotraffic AB, in 1988. The debate on nuclear energy downsizing, and the Chernobyl incident in 1986 meant that the research focus was temporarily moved from biomass gasification to coal gasification (Sandén & Jonasson, 2005). However, after the publication of the 1991 Energy bill (Carlsson & Molin, 1991), biomass-based energy research regained its policy support, and thus also biomass gasification. The attempt by Ecotraffic, the municipality of Trollhättan and Nycomb Synergetics to set up a methanol production facility in the mid-1990s indicates a return of high methanol expectations. EU funds were gained to conduct a feasibility study, but the project did not gain any further support (Sandén & Jonasson, 2005). Methanol fuel initiatives would not reappear until the late 1990s.

Alongside the end of the oil crisis, the lack of funds and limited institutionalization, one reason for the disappearance of methanol fuel was competition from alternative fuels. While the Government gave continued support to M100 R&D and trials in the early 1980s, heads of research at Volvo and the alternative fuel programme part of the Energy Research Programme started to see the ethanol option as more promising than methanol (Nilsson, 1984) (see below).

7.1.2. Methanol SNM analysis, 1970-1986

Methanol, 1971-1986																
	1971	**1972**	**1973**	**1974**	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**
Network					SMAB						SDAB					
Field trials	Volvo 10 vehicles and R&D															
									SMAB 1000 M15 vehicles							
									SMAB pumps							
										SMAB 2 M100 buses						
														SDAB 22 M100 vehicles		
R&D fuel					KTH, Studsvik gasification				Mino pilot							

Table 17: Methanol development, 1971-1986

Network actors	Biofuel	Expectations	Key experiments	Learning	Socio-technical configurations
Volvo, SMAB/SDAB (government + Volvo), researchers	Methanol use (pure and in blends) and production	Triggered by oil crisis; expectation of creating a low blend market niche based on domestic methanol production to substitute for oil and become self-sufficient in fuel. Expectation of local environmental benefits as well. At end of period, promise of pure methanol use and natural gas based methanol as short-term solution due to problems realizing bio-based methanol.	R&D bio-based methanol difficult to realize, hence natural gas methanol in short term. Successful M15 trial with 1000 vehicles, but focus change to M100.	Gasification for bio-based methanol remains a bottleneck. Fossil methanol works for both M15 and M100. Dependence on government funding.	Temporal M15 and M100 niches with weak fossil methanol distribution infrastructure which disappeared once financial support vanished.

The main *actors* promoting methanol were Volvo and the government, initiating an organization for methanol cooperation called SMAB/SDAB. Together with researchers and public companies, SMAB/SDAB gained increasing funds to evaluate and develop bio methanol production and use in vehicles until 1984. In the late 1970s, with the set up of a large-scale natural gas based M15 vehicle experiment, Volvo withdrew from its leading role in the network while other vehicle producers, fuel distributors and natural gas actors joined the network and trials. The fast expansion of the methanol R&D and vehicle experiments can partly be explained by the powerful network of actors from part of the government, the vehicle and the fossil fuel (natural gas) regimes. In addition, the wide variety of network actors and their aligned activities within SMAB/SDAB are likely to have contributed to niche development.

In terms of the *expectations* driving the experiments, the oil crisis had a positive effect. It strengthened the initial expectations for bio methanol as the best substitute for fossil fuels because it was easy to handle, could rely on domestic feedstock and conventional engine technology, and had the potential to become relatively cheap and generate environmental benefits. These general expectations were connected to promises of a future commercial market, in particular the use of M15 in gasoline, which in turn attracted network actors. In the late 1970s the promise of natural gas methanol as a relatively cost-efficient and environmentally friendly short-term fossil fuel substitute arose. The shift to fossil methanol expectations was related to the lesson that technical bottlenecks prevented the short-term commercialization of bio-based methanol. Research and large-scale trials with fossil methanol led to the lessons that the fuel technology worked well in vehicles and that it contributed to environmental benefits, which strengthened the expectations for natural gas methanol. Despite the success of a large-scale M15 trial, the government directed the funds for field trials to a small-scale M100 pilot instead with the expectation that it would substitute for oil more efficiently. This however did not mean that the promise of lower methanol blends vanished, but they were dependent on funding to continue. Despite the positive lessons and a plan to scale up the M100 trial and commercialize bio-based methanol production, the government ended the subsidies in 1984.

The withdrawal of the government from the project, including abrupt termination of methanol funding, meant the end of the niche. However, energy production was still funded which enabled continued R&D on gasification. The M100 trial, which ran until the funds already granted ended in 1986, had like the M15 trial only a temporary infrastructure. This temporary infrastructure and the lack of fuel and vehicle standards made the niche easy to break down.

7.1.3. The development of the methanol/alcohol discourse, 1970-1986

With the emergence of the oil crisis in 1973-1974, the government became aware of the great dependence on oil that had built up during the 1950s and 1960s (Zacchi & Vallander, 2001). This concern resulted in the return of an oil substitution discourse, which had been dormant since the end of the Second World War.

Before the emergence of the oil substitution discourse, research carried out by Volvo in collaboration with the National Board of Economic Defense (ÖEF) concluded that the current emergency fuel, wood gas, was outdated and no longer fit for the modern vehicle engine technology (SMAB, 1978). Volvo argued that methanol was the best emergency fuel option. The most important argument in favour of methanol, part of the methanol discourse, was that it could be produced from domestic materials, e.g. wood, peat and limestone. It was also easy to handle and cheap compared to the other fuel alternatives. Finally, it had environmental benefits (Abrahamson, 1975). The environmental benefits fit with contemporary environmental concerns, referring to the potential of methanol to substitute for lead as an ignition improver and reduce the emissions (nitrogen compounds, nitrogen oxides) that cause acid rain (Abrahamson, 1975; Statens energiverk, 1989). This indicates attempts to embed the early methanol discourse in the oil substitution discourse and the environmental discourse. However, judging from contemporary argumentation (see Abrahamson, 1975; SMAB, 1978), environmental concerns were secondary to the oil substitution discourse.

Volvo was a strong actor which managed to involve the government in the methanol discourse. This was exemplified by the set up of SMAB, co-owned by the government and Volvo (SMAB, 1978), as well as the increasing amount of R&D funds for methanol development from 1975 to 1985 (Sandén & Jonasson, 2005). The automobile branch and related interest organizations provided additional support for the methanol discourse (Walldén, 1975). A lot of academic research also demonstrated the potential of methanol.

> A number of investigations concerning the operation of otto [sic] engines on methanol and mixtures of methanol and gasoline are reported in the scientific literature. The results of utilization of methanol fuels have been very positive. Considerable improvement of the efficiency as well as substantially decreased emissions have been reported. (SMAB, 1978: 66-67)

In the mid-1970s, fear of another oil crisis emerged (see Abrahamson, 1975). The government no longer saw oil substitution measures, focusing on energy saving and large nuclear energy R&D funds, as sufficient (Vedung, 2001). Motivated by the increased urgency for oil substitution, the government appointed an Energy Commission in 1976, which recommended a shift to a broader alternative fuel discourse. Although the Commission continued to present methanol as the best alternative fuel option, it pointed out that methanol from domestic feedstock was an immature technology that could not substitute for oil in the short-term. Hence, the Commission advised broadening the alternative fuel agenda to investigate more alternative fuel options instead of focusing on methanol alone. A second recommendation was to implement conventional, fossil-based fuel alternatives in the short term in addition to the development of long-term methanol solutions based on domestic feedstock, which was previously the sole focus (Johansson, 1980). That a broad alternative fuel discourse was emerging was further confirmed by the 1978 Government bill, in which the policy advice set out by the Commission was closely followed and approved by parliament in 1979 (Ahlmark & Johansson, 1978; Kignell, 1981: 2-1). That the government was motivated by a strong oil substitution discourse was visible in the arguments used in the Bill, and by the appointment of an Oil Substitution Commission in January 1979.

> The Swedish Commission for Oil Substitution has been set up with the object of coordinating work directed towards the introduction of fuels which can replace oil. The substitute sources upon which work is being concentrated are coal, forest waste and other wastes, peat, synthetic motor fuels and solar heating. (Swedish Commission of Oil Substitution, 1980: foreword)

As the above quote and Haegermark (2001) indicate, the primary aim of the Commission for Oil Substitution was to study and propose measures for introducing alternative fuels and solar energy in the short term. The definition of synthetic fuels used in the quote included methanol, but represented a policy shift to support for several fuel alternatives.

As argued by Statens Energiverk (1984b: 23), the term 'oil substitution' (author's translation) was frequently used in relation to energy politics in the early 1980s in order to give a focus to the policy and legitimize the investment made. Nevertheless, additional discourses and developments at the general energy policy level can explain the direction of the alternative transport fuel discourse.

The oil substitution discourse also gained increased attention in the general energy domain. However, political agreements and various discourse developments over time meant that the means to substitute oil had become scarce. In the 1960s, a political agreement was made that forbade further exploitation of rivers for hydropower. This was due to a strong environmental discourse presenting hydropower as devastating for flora and fauna along Swedish rivers. The discourse presented nuclear energy as a solution and the most environmentally friendly energy alternative (Kaijser, 2001). However, unanimous support for nuclear energy ended in the early 1970s when the Centre Party, promoting farmer and environmental interests, pointed out the environmental risks. The Centre Party gained followers and an anti-nuclear discourse soon emerged. At the time of the first oil crisis, the pro-nuclear discourse still dominated anti-nuclear sentiments and the majority of the energy R&D funds went to nuclear energy development. However, in the second half of the 1970s the anti-nuclear discourse grew in parallel with the oil substitution discourse. As a result, negotiations started between the anti-nuclear coalition led by the Centre Party and the Left Party Communists and pro-nuclear coalition led by the liberal party, Folkpartiet, the right wing conservative party, Moderaterna, and the Social Democrats on how to deal with the threat of another oil crisis. They reached a compromise in 1979. In the interests of the Liberal, Conservative and Social Democratic lobby, annual support for nuclear R&D remained. The Centre Party accepted this on the condition that the funds would not to be increased over time and that increased funding was given to the biomass energy sector. The result was an energy policy geared towards actual oil substitution measures with a larger focus on biomass to serve this purpose (Haegermark, 2001).

While the 1978 Energy Commission report broadened the biofuel discourse, its focus was on synthetic fuel options that were not necessarily bio-based, at least not in the short term. The 1979 political compromise on future energy policy created additional opportunities for the development of bio-based fuel options, in particular for ethanol which emerged in the agricultural and the chemical sectors, as well as methanol. Because of these developments, the government ordered increased research on alternative fuel options. The publication of two reports showed the growing interest in alternative fuels: first, the report by the Oil Substitution Commission (1980) focused on synthetic fuel options; and, second, a report by the Agricultural

Ministry (Jordbruksdepartementet, 1980), the first serious investigation of the potential of ethanol in modern times.

While subsidies for methanol continued to grow, the movement towards a broader alternative fuel discourse meant that the methanol discourse became increasingly vulnerable to competing alternatives. This development was reflected in the decision by SMAB to replace its sole focus on methanol with a broader alternative fuel agenda and the follow-up decision by Volvo to reduce its stake in SMAB from 40% to 10% in 1979 (DFE, 1981). Of the many alternative fuels considered, ethanol became one of the most interesting alternatives next to methanol. This led to the development of an alcohol discourse, which successively substituted for the methanol discourse. This discourse shift was discernible in the many reports in the 1980s that used terminology focused on alcohols instead of methanol or ethanol (e.g. Swedish Commission of Oil Substitution, 1980; Swedish Commission for Oil Substitution, 1982; Motoralkoholkommittén, 1986a; Statens energiverk, 1986). Another example of this discourse shift is the name change of the Swedish Methanol Development Co. Ltd. (SMAB) to the more neutral The State's Propellant Technology Co. Ltd. (SDAB) in 1981 (DFE, 1981).

SDAB remained the biggest promoter of methanol, although its lobbying approach became less aggressive due to the growing alcohol discourse (see Brandberg, 1981; Salomonsson, 1983; Bertilsson et al., 1986). The government was another large supporter of methanol in the early 1980s, despite the broadening of the alternative fuel agenda. Government documents continued to present methanol as cheaper than alternative fuels and thus the best fuel option. They promoted the start of methanol trials and, in line with the arguments of the 1978 Energy Commission, argued that methanol production from fossil feedstock should be introduced as a bridging technology until methanol technology based on domestic feedstock was sufficiently mature (Ahlmark & Johansson, 1978; Swedish Commission of Oil Substitution, 1980; Industridepartementet, 1983; Näringsutskottet, 1983). The SDAB, government institutions and selected researchers presented methanol from fossil feedstock as a good substitute for oil. Their argument was that fossil methanol was more reliable than oil because of the variety of feedstocks for methanol production, (e.g. natural gas, coal, and less attractive (high sulphur) faced less competition and could be imported from less politically unstable countries. In addition, the methanol coalition presented the use of fossil-based methanol as a route to a more environmentally friendly bio-based methanol. The coalition also argued that fossil methanol was more environmentally friendly than gasoline (Swedish Commission of Oil Substitution, 1980; Kignell, 1981; Brandberg, 1981; Industridepartementet, 1983). The continued strength of the methanol discourse was reflected in the successive increases in government subsidies for methanol R&D until 1984 (Ahlmark & Johansson, 1978), support for a pilot plant (Miljö och Energidepartementet, 1989) and tax exemptions for large M15 trials in 1979 and M100 in 1983 (Bertilsson et al., 1986; Statens energiverk, 1986).

The methanol discourse retained its power, despite the existence of an ethanol discourse (see Jordbruksdepartementet, 1980) with a seemingly better fit with the environmental and oil substitution discourses, given its reliance on bio-based and domestic feedstock. This indicates the relative power of the methanol discourse and its coalition actors. One of the recurring arguments in the methanol discourse that prevented further ethanol discourse development was that ethanol was too expensive (e.g. Abrahamson, 1975; SMAB, 1978; Swedish Commission of Oil Substitution, 1980).

Despite the level of SDAB and government support for methanol and ambitions to realize a large-scale implementation in the 1980s, they did not manage to set up a detailed methanol implementation plan. This was partly due to uncertainty with regard to methanol production, distribution, use and international market development. One example of this uncertainty is the abrupt change in the government's methanol introduction strategy.

Initially, a focus on the introduction of a mix of 15% (M15) methanol in all gasoline was considered best, but this was later replaced with a preference for pure methanol (M100) with the argument that this would lead to faster oil substitution (Swedish Commission for Oil Substitution, 1982; Industridepartementet, 1983; Näringsutskottet, 1983). The failure to institutionalize methanol further indicates that the methanol discourse had reached its peak. General developments, such as the growth of an alcohol discourse that created room for an emerging ethanol discourse, are likely to have contributed to the eventual decline of the methanol discourse. In addition to the ethanol discourse, the general promotion of a variety of alternative fuels and criticism of methanol and the methanol policy plan set out by the government are likely to have contributed to the decline of the methanol discourse.

A group of engineers and scientists in the Energy Working Group of the Technical Universities (Tekniska högskolornas energiarbetsgrupp, THE) argued that the bottlenecks for bio-methanol were being taken too lightly, and that the process for bio-methanol production was very difficult and expensive. Hence, the THE warned of the potential lock-in that the current focus on methanol might create (Lagermalm & Luthman, 1980; Schwanbom & Walldén, 1981). In fact the THE and the contemporary bioenergy promoters at the time were against biofuels in general and argued that it would be more efficient to use Swedish biomass resources for local energy and heat production to reduce oil dependence (Lagermalm & Luthman, 1980). As emergency fuel for the transport sector, they promoted less attractive fossil options such as coal or natural gas for liquid fuel production, in particular synthetic gasoline from natural gas. While the general argument was that synthetic gasoline production was potentially more expensive than methanol, they argued that a better fit with current infrastructure and engine technology would make the synthetic fuel alternative cheaper. Moreover, according to the THE, synthetic gasoline had lower emissions than methanol (Lagermalm & Luthman, 1980; Schwanbom & Walldén, 1981). Researchers at the Energy Technology Centre at Chalmers Technical University were even more critical of methanol than the THE. They argued that oil dependency would increase if using fossil methanol instead of gasoline due to the high energy loss when converting natural gas to methanol. Moreover, they argued that new emissions would emerge that were more harmful for humans and the environment than the emissions from gasoline and lead. As an alternative, the researchers promoted the direct use of natural gas or electricity in vehicles (Ny Teknik, 1980).

In addition to these groups of scientists criticizing methanol, the big trade organizations for Swedish oil (Svenska Petroliuminstitutet) and the automobile industry (Bilindustriföreningen) and the main LPG company Gasol AB were hesitant about the short-term methanol implementation policy that the government suggested. Their main concern was the isolated fuel market that large-scale implementation of methanol would imply, which would hinder international transport and thus Swedish trade and economic growth. Moreover, methanol implementation involved costly investment in infrastructure, engines and standards development. These actors demanded a wait-and-see policy, to wait for results from the methanol trials in Germany as well as the intentions with regard to the setting up of a methanol market before making further decisions on Swedish methanol implementation (Swedish Commission for Oil Substitution, 1982: see appendix). The industrial actors may have been less critical of methanol than the scientists promoting alternative fuels to alcohol. However, the arguments of the industrial actors reflect a highly institutionalized fossil fuel discourse, which is likely to have prevented further institutionalization of the methanol discourse.

Alongside the actors promoting other alternative fuels or resisting short term methanol implementation, changing general discourses are also likely to have contributed to the decline of the methanol discourse. Although the international oil markets stabilized in the early 1980s (Statens energiverk, 1984a; see also Dutch case study), Swedish oil prices were kept high until 1984 (Statens energiverk, 1990). Falling oil prices and the growing idea that future fossil fuel supply was secure in the short term meant the oil substitution discourse lost support. Consequently, interest in fast and large-scale implementation of methanol vehicles and methanol production decreased. The Swedish Energy Authority (1984a) made this obvious in its R&D plan for the period 1984-85 to 1986-87:

> The development efforts of gasification technology to produce synthetic gas from peat and biomass have primarily aimed to develop a process that can be used for methanol production. During the period [read: coming three-year R&D programme] this work will be terminated. (Statens energiverk, 1984a: 54-55, translated by the author)
>
> [...] the refinement activities will change character from efforts to develop technology and processes to produce alternative propellants [read: methanol] to processes that more generally aim to produce fuel gas or other gas and liquid products for oil substitution. The reason is that the prognoses for energy supply in the transport sector is judged to be relatively good and that possible alternatives are expected not to become profitable before 1990-1995. (Statens energiverk, 1984a: 53, translated by the author)

As is indicated in the quote, the bio-methanol R&D subsidy was ended because bio-methanol was not expected to be able to compete with fossil fuels in the coming 10 to 15 years. After a trend of increased methanol funding since 1975, a policy that ended funding for bio-methanol research and methanol field trials after 1984 marked a radical policy shift (DFE, 1981; Statens energiverk, 1984a).

However, there were still arguments in favour of having an emergency fuel. Farmers' interests presented ethanol as a more suitable emergency fuel option than methanol. They argued that small-scale ethanol production facilities could be set up faster, and thus be cheaper and more flexible in a crisis situation compared to methanol which required expensive and large-scale production plants and infrastructure for cost-efficient production (Jordbruksdepartementet, 1980; Motoralkoholkommittén, 1986b). This was an attempt by the ethanol coalition to gain support from the self-sufficiency discourse, that is, the propagation of neutrality and for emergency solutions, which had been strong during the World Wars and in the post-war era. The self-sufficiency discourse became visible once the more radical oil substitution discourse lost ground. The environmental discourse also grew. In the early 1980s, SDAB stated that 'a substantial demand for alternative fuels with improved environmental qualities has emerged among the general public as well as the municipality/health care administrations and counties' (SDAB, 1982: 11). The environmental discourse, which had primarily been concerned with local emissions and health concerns in cities, continued to grow and became broader in the second half of the 1980s, to include global environmental concerns connected to climate change (Statens energiverk, 1990). Sandén and Jonasson (2005) link the environmental discourse developments to growing criticism of methanol. Ethanol, on the other hand, gained recognition for its renewable fuel qualities, as is described below.

This overview shows that the methanol discourse lost its strength, first, with the reduced promise of bio-methanol production and second, when the oil substitution discourse lost strength, which meant that investment in a large-scale methanol plant was no longer feasible. In the late 1980s, once the oil substitution discourse had weakened and the environmental discourse dominated the fuel debate, support for fossil-based methanol became harder to defend.

7.1.4. Methanol/alcohol discourse analysis, 1970-1986

General policy developments affecting methanol					
Policy	**Level**	**Year**	**Type**	**Size SEK**	**Explanation**
Energy Research Programme	Government	1975-1984	R&D	26 million for 1975-1978, 76.4 million for 1978-1981, 177 million for 1981-1984	Funds for alternative fuel development increased over time. Methanol dominated the funds.
SMAB	Government, industry	1975-1978	R&D, communication	20 million	Swedish Methanol Development Company (SMAB), owned by Volvo and the government. Focus on methanol.
	Government, industry	1979-1981	R&D, communication	?	Change to general alternative fuel focus, Volvo reduces ownership.
1979 energy policy compromise	Government	1979	Energy policy	?	Party conflict with regard to nuclear energy results in compromise with increased policy support for bioenergy/biofuel.
SDAB	Government, industry	1981-	R&D, communication	?	SMAB becomes the State's Propellant Technology Company (SDAB). Alternative fuel focus
Tax exemption methanol	Government	1980-	regulation	?	In 1980, tax exemption on methanol of 50% per volume. In 1981 exemption covers all alcohol fuels (e.g. MTBE, ethanol)
Energy Research Programme	Government	1984-1987	R&D	56 million	Alternative fuel funds SEK 56 million of total funds SEK 1191 million. 1984 decision to end bio-methanol research. First time R&D funds decline.

Methanol initiatives					
Policy/Initiative	**Level**	**Year**	**Type**	**Size SEK**	**Explanation**
10 vehicles - Volvo	Industry	1971-1975	Field trial	?	Volvo tests methanol in 10 diesel/Otto vehicles.
MINO gasification plant	Government	1975-1984	R&D/pilot	?	In late 1970, the MINO gasification installation starts running. It aims to study gasification technology and potential bio-methanol production.
Energikombinatet Nynäshamn-Stockholm	Government, municipality and industry	1978-late 1980s	Feasibility study	Government 650 000, partners 1 million	SMAB coordinated feasibility study of combined methanol, energy and heat production. Fossil fuel based, only biomass in times of crisis.
1000 M15 vehicles	EU, Government, industry	1980-1982	Field trial	?	SDAB-led trial with 1000 M15 vehicles with slightly adapted engines and 19 M15 distribution pumps. Part of larger EU project.
Buses - Stockholm Public Transport	Government, municipality, industry	1980-1982	Field trial	Total cost 1.18 million	Two methanol/diesel buses using two-fuel Volvo engine.
	Industry	1982-	R&D	3 million government	Volvo aims to optimize the two-fuel methanol engine technology.
22 M100 vehicles	Government	1984-1986	Field trial	9.9 million total cost, government main financer	SDAB trial with M100 in 22 slightly modified Otto vehicles.

Table 18: Methanol-related policy development, 1975-1986

Biofuel	Discourse	Mobilization/ impact of wider discourses, events and policies	Discourse coalition	Target audience	Key activities, strategies	Resulting space/policy creation or disruption
Initial focus on methanol production, later also on field trials with low blend and pure use.	Best alternative to fossil fuels due to reliance on domestic biomass resources, relatively cheap, fit with engine technology and environmental benefits. In the late 1970s, shift to promotion of natural gas methanol in the short term and acceptance of other alcohols, such as ethanol, as a complement. In addition, low blend focus shifted to pure methanol use.	Embedded in the general oil substitution discourse, and the environmental and self-sufficiency discourses.	Led by the vehicle industry and the government in SMAB/ SDAB and backed up by scientists	Wider public as audience to prove that biofuel is indeed a good alternative	Lobbying took place to convince the public. Example of activities was the bridging argument that fossil methanol was a good environmental and oil substitution solution until bio-methanol matured, even though bioethanol – a mature alcohol technology based on domestic feedstock – was already available.	Successive increases in government subsidies for methanol R&D until 1984; support for a pilot plant and tax exemptions for a large scale M15 trial and a later M100 trial. However, in mid-1980s all funding ceased.

The 1973 oil crisis aided the development of the methanol discourse. According to the methanol discourse, methanol was the number one alternative to fossil fuels due to its reliance on domestic biomass resources, relatively cheap price, relative good fit with conventional engine technology and environmental advantages. With the increased oil substitution urgency in 1979 and the inability to realize bio methanol production in the short term, the discourse shifted towards a methanol/alcohol discourse. This discourse promoted natural gas methanol as a short-term solution and saw other alcohols (ethanol) as complementary to methanol. Later on the discourse shifted from a focus on low blend to pure methanol use. The discourse had strong embedding in the more dominant oil substitution discourse. Once the oil price started to stabilize in the 1980s, the oil substitution discourse weakened and the methanol discourse had to rely on its embedding in the environmental discourse alone.

The vehicle industry and the government led the methanol coalition by means of a joint company – SMAB. With the acceptance of other feedstock and fuels by the methanol discourse, SMAB changed to a more fuel neutral name – SDAB. Additional coalition actors were scientists. The wide variety of actors, their authority, access to resources and close collaboration explain the fast and successful growth of the discourse. Nevertheless, a reduced commitment by the vehicle industry and scientists from 1979 reduced the power of the coalition. Despite this, the government increased funds until 1984 when it decided to cease funding new projects.

The coalition directed its lobbying activities to the wider public through the media and various scientific reports. A successful strategy was the argument that natural gas based methanol was the best environmental and oil substitution solution on the short term, despite the availability of a mature bio-based and domestic alcohol alternative – ethanol.

Support for methanol dominated other biofuel alternatives from 1975 until the mid-1980s. As is indicated in Table 18, policy measures resulting from this discourse were initially focused on R&D funds, which were regularly increased until the mid-1980s. From 1980, these funds were complemented by tax exemptions for large scale methanol vehicle trials, mainly M15 and later a smaller M100 trial. Most policy measures were temporary, apart from a change in fuel taxes, which indicates that the overall institutionalization of the fuel was limited.

The fall of the methanol discourse was partly related to the immaturity of bio methanol and a shift away from oil substitution to environmental concerns, but also because of the emergence of competing discourses. One example is the bio energy discourse, which claimed that biomass use for energy instead of fuel was more efficient. Another was the ethanol discourse, which disputed the argument that methanol was a more environmentally friendly and cheaper emergency fuel option.

7.2. ETHANOL TAKES THE LEAD, 1980-1997

This section describes the emergence and development of ethanol fuel in the period 1980-1997. First, I present the development of the ethanol niche followed by an SNM analysis. Second, I describe the political processes leading up to ethanol policy followed by a discourse analysis.

7.2.1. Ethanol niche development, 1980-1997

As is explained in the chapter 6, the production of industrial alcohol from sulphate lye for emergency purposes was subsidised by the government until the early 1980s. In addition, food alcohol production played a traditional role in Swedish society. Despite this, ethanol was not considered a useful option for the transport sector when the urgency for fuel alternatives increased in the 1970s. Instead, methanol experiments were started by the automobile industry and the government because it was considered less expensive and more flexible with regard to raw materials compared to ethanol (e.g. Walldén, 1975; SMAB, 1978). Nevertheless, once it became clear that the agricultural sector was in trouble, interest in ethanol emerged.

Ethanol production

In 1978 the sugar industry SSA (Svenska Sockerfabriks AB) tried to end unprofitable sugar production from sugar beet at a factory in the town of Karpalund. Both the Swedish association of sugar beet farmers and the Swedish association for factory workers opposed SSA's plans. To resolve the issue, the government started negotiations with SSA and the sugar beet farmers in 1979. Subsequently, the idea of converting the sugar factory to an ethanol production plant emerged. The government made an agreement with the sugar industry to keep the factory running for another two years to give sufficient time for research and a final decision on its future (Jordbruksdepartementet, 1980).

The Ministry of Agriculture, Nature and Food Quality set up a commission to research the potential of ethanol for the transport sector. The report published by the commission showed the promise of ethanol from surplus or damaged wheat or sugarbeet. The commission presented ethanol as better than methanol due to the ability to produce it from domestic, renewable feedstock in the short term. Unlike ethanol, the short term methanol option was fossil-based, and therefore neither environmentally friendly nor domestic. In this way, the promise of ethanol was well in line with the goals of oil substitution and reduction in environmental impact (Jordbruksdepartementet, 1980). Even the Commission on Oil Substitution, which researched synthetic fuel options, saw its relatively cheap production costs as a benefit of ethanol fuel and acknowledged the potential for complementing methanol fuel blends with ethanol when necessary (Swedish Commission of Oil Substitution, 1980: 1; Swedish Commission for Oil Substitution, 1982).

With regard to the potential of the Karpalund sugar factory to produce ethanol, the positive expectations raised with regard to ethanol as a fuel alternative were encouraging, but uncertainty remained when it came to the costs. According to a limited ethanol distribution model calculation by OK, an oil distribution company with cooperative ownership, the minimum cost of the tax exemption necessary to reduce the ethanol price to that of gasoline was estimated at SEK 0.70 per litre. According to the Agricultural Ministry, more detailed research on ethanol costs was necessary before government support for the Karpalund factory could be agreed (Jordbruksdepartementet, 1980). As is outlined in the methanol section, the government gave a tax exemption to ethanol in 1981 (Industridepartementet, 1983). However, this does not appear to have been sufficient incentive to start ethanol production at Karpalund, since the project was terminated (Swedish Commission for Oil Substitution, 1982).

However, in parallel with the Karpalund project another ethanol project idea developed in 1979. SMAB, the company Alfa-Laval AB and the Federation of Swedish Farmers (Svenska Lantmännens Riksförbund, SLR) started planning a combined plant producing ethanol and proteins for animal feed based on wheat. They applied for funds from the government. In 1981 a subsidy of SEK 26.5 million for the construction of a demonstration plant was granted and another SEK 3.6 million was given to compensate for later revenue losses due to start-up problems (Statens energiverk, 1986). In addition, the project benefitted from the ethanol tax exemption (Industridepartementet, 1983). With assistance from SDAB, Alfa-Laval and the SLR set up a company, AB Agrienergi, to manage the project. The original plan to start production in 1982 was postponed. The plant used the BIOSTIL-ethanol process technology developed by Alfa-Laval. This process had a particularly efficient fermentation phase, an ethanol production phase and refinement of the left over liquids from the fermentation process (SDAB, 1982: 91). The plant was located in Lidköping in the Skaraborg County. The plant was called Västergötlands Lantmäns etanolfabrik, meaning the ethanol plant of the farmers of Västergötland region. The plant aimed to produce 20 000 litres of wheat ethanol a day (Nilsson, 1984). The oil distribution company OK supported the project. According to OK's initial economic calculations, a 93 octane gasoline fuel mixed with 10% ethanol would equal the quality of a low-lead 97 octane gasoline and have a cost equal to normal 97 octane gasoline (Jordbruksdepartementet, 1980). Based on this assumption, OK and the ethanol producers started negotiations, which led to a 4% implementation of ethanol in gasoline at OK fuel stations. OK had to complement the domestically produced ethanol with imported ethanol to make the 4% ethanol blend possible (Statens energiverk, 1986).

The demonstration plant successfully produced ethanol from 1984 to 1987, which led to the scaling up plans by the farmers' organizations, the SLR and the Federation of Swedish Farmers (LRF) (Bremen, 1991). The LRF requested funding for the follow-up plant. Eventually, in 1991, the government (Carlsson & Molin, 1991) offered renewed financial support for ethanol production. However, according to Sandén and Jonasson (2005) and Bremen (1991), the farmers were not willing to set up the production facility without a guarantee of a future ethanol market – a long-term agreement which the oil distribution companies were not willing to offer (ibid.). In addition, with accession to the EU in 1995, the EU agricultural funds paid for the exportable wheat surplus, which made the production of ethanol less financially attractive for farmers (Sandén & Jonasson, 2005). As a result, the ambition to construct a wheat ethanol plant was put on hold until the late 1990s.

In addition to the activity among farmers' organizations, the chemical industry, which produced alcohol from sulphate lye in Örnsköldsvik, a town in the north-east of Sweden, saw an opportunity in the use of ethanol as a transport fuel. The pulp and paper companies Mo and Domsjö (Modo) AB produced the sulphate ethanol and Swedish Ethanol Chemistry (SEKAB), owned by Modo and Beryl Kemi, refined it to ethanol fuel. The Swedish Emergency Management Agency (ÖCB) subsidized sulphate alcohol production for emergency purposes, but this was not sufficient for SEKAB's business ambitions. By means of government investment loans, SEKAB increased its commitment to sulphate ethanol. Efforts were made to increase economic efficiency and search for new markets. Consequently, local municipalities in the region of Örnsköldsvik, the farmers' organization Lantbrukarnas Riksförbund (LRF), representing both agrarian and forestry interests, Beryl and SEKAB set up the Foundation for Swedish Ethanol Development (Stiftelsen Svensk Etanolutveckling, SSEU) in 1983 (Sandén & Jonasson, 2005). The aim of the foundation was to explore the potential to produce and use biomass-based ethanol in the transport sector, with a particular focus on cellulose ethanol (Rehnlund & Van Walwijk, 2005). Financial support came from the Ministries of Industry, Defence and Agriculture (Sandén & Jonasson, 2005).

The SSEU was one of the driving actors behind cellulose ethanol technology, but research in relation to ethanol had started earlier. As is indicated in Table 16, the first R&D funding earmarked for the Energy Research programme on the development of cellulose ethanol was SEK 3.5 million, designated for the year 1980/81. This was far less than the SEK 75.7 million that methanol had been awarded in the period 1975-1981. Later, when the government withdrew methanol funds, it increased ethanol funding to only SEK 5 million, while other potential alternative fuel conversion routes such as pyrolysis gained SEK 10 million (Statens energiverk, 1984a). These figures show a reduction in the government's ambition to fund biofuel development. However, SSEU's ambitions to push cellulose ethanol had only just begun.

From 1984, SSEU initiated advanced cellulose ethanol research in cooperation with universities. The expectation was that the production of ethanol from wood would produce higher efficiencies than the traditional ethanol production method from sugar and starch. In addition, SSEU pushed for the set up of a cellulose ethanol pilot plant, but researchers declined to participate in such a project for over a decade (Sandén & Jonasson, 2005; Zacchi & Vallander, 2001). In the many ethanol R&D projects outlined below, the reason for researchers' lack of interest in up-scaling the technology is likely to be related to its immaturity.

There were three main so-called hydrolysis techniques, which break down cellulose to enable cellulose fermentation to ethanol. First, the 'weak-acid' technology, which was developed by an international research collaboration coordinated by the SSEU. Combining the names of the collaboration partners (Canada, America, Sweden Hydrolysis) gave this particular technology process its name: CASH. A second process was 'strong acid' technology, the Concentrated Hydrochloric Acid Process (CHAP), based on recycled paper as a raw material at Chematur Engineering AB. A third technique was the development of enzymatic technology at the lab-scale at Lund Technical University. According to SSEU, the CASH process was the most mature process, ready for demonstration in a large-scale plant. According to Chematur and the Waste processing company of the municipality in Stockholm (SKAFAB, Stockholms Kommuns Avfallsförädling), CHAP technology was ready for a preliminary project in a large-scale plant. The enzymatic technology was the least developed, but considered ready for a large-scale laboratory bench test (Östman, 1998).

In 1993, the government set up a three-year R&D programme, the Ethanol Development Programme, with a budget of SEK 15 million per year. The programme's aim was to 'to verify and evaluate all processes of ethanol production from cellulose in a larger scale context' (Östman, 1998: 12, translation by the author). The National Board for Industrial and Technical Development (Nutek) organized a call for proposals in June. By November, Nutek had received about 20 proposals, but rejected them all. The proposals all focused on similar processes, pilots or preparatory processes to the CASH process, for which the estimated cost of the final ethanol product Nutek considered too high in comparison to the price of conventional ethanol.

Instead of granting programme funds, Nutek decided to set up a general system study evaluating the potential for carrying out ethanol processes at industries and firms with similar activities (Östman, 1998). Combining production in this way was known as bio-refinery (Månsson, 1998)· At first, Nutek ordered an evaluation of available ethanol technology based on Swedish experiences and the international literature. It was concluded that Swedish ethanol technology development was on a par with international developments, but that none of the processes were mature enough for scaling up to a pilot or demonstration plant. There had been no demonstrations of the vital process elements, which created great technology uncertainties (Östman, 1998). For the CHAP process, the evaluation showed negative environmental effects and high costs, and the programme board decided to cut funding at an early stage. The most promising and mature technology, CASH, was not considered able to deliver a competitive ethanol production process. Nevertheless, the evaluation reported potential synergies where the CASH process was included in a bio-refinery production strategy. Finally, the evaluation reported economic uncertainties about the least mature enzymatic process technology due to the high price of enzymes (Östman, 1998).

Based on these insights, Nutek made additional revisions to the Ethanol Development Programme in 1994. The main aims of the programme became to develop a process alternative that could increase ethanol output, and to identify and resolve technological bottlenecks. The ambition was to construct a biorefinery to pre-project a CASH plant (Östman, 1998).

The SSEU lobbied for funds for a CASH demonstration plant at Domsjö. The SSEU was denied funds from the bioenergy research programme, FABEL, and the Ethanol Development Programme. After a lengthy evaluation process, the Ethanol Development Programme concluded that it could not agree the SSEU's request for the SEK 16 million needed for the pilot. After this setback, ethanol actors lost interests in large development projects involving CASH. However, general R&D activities with regard to other weak-acid hydrolysis technologies were funded.

The Ethanol Development Programme funded the construction of a bench-scale installation of the enzymatic hydrolysis process run by the Lund University of Technology. To resolve the bottleneck of the high price of enzymes, researchers were funded to experiment with their own enzyme production. They were also experimenting with alternative enzyme routes, such as a combined enzyme and fermentation process known as Simultaneous Saccharification and Fermentation (SSF). Other projects funded by the programme focused on increasing the efficiency of the fermentation process, i.e. the conversion of the sugars to ethanol, or finding ways to exploit by-products. The loss of sugars in the production process was one of the main problems. By using genetically modified yeasts, researchers could increase the output of ethanol in sugars from the conventional fermentation processes of crops. The expectation was that modified yeasts could also increase wood-related sugars such as hexose. Additional processes which fermented other wood sugars, so-called pentose, were expected to increase the efficiency of cellulose ethanol even more (Östman, 1998). According to Östman, fermentation technology advances in the USA fed technology expectations in Sweden. Alongside fermentation technology, finding a way to exploit the by-product lignin was of interest since a normal CASH process produced four times more lignin than ethanol. Explorations were mainly directed to the use of lignin for energy production in neighbouring industries or for the production of the steam required in the CASH process.

The revision of the Ethanol Development Programme's aims delayed it by a year, which affected programme activities between 1994 and 1997. The final project report concluded that the process technologies funded by the programme had increased potential ethanol output by approximately 50%. A second conclusion of the report was that technological progress had not altered ethanol production costs very much. The expected cost of cellulose ethanol was SEK 5 per litre or SEK 4 per litre in case of a biorefinery process. This estimated price was comparable to the contemporary production costs of ethanol from grain. There was a general assumption that the role of cellulose ethanol would increase once the resources for grain ethanol were exhausted (Östman, 1998).

Technology	Actors	Number of projects
Fermentation	Chalmers Technical University Gothenburg University Lund University	8
Weak hydrolysis	Technical Research Institute of the Foresting Industry (STFI)[56] Lund University Mid-Sweden University Chalmers Technical University Lund Technical University	7
Enzymatic hydrolysis	Lund Technical University Lund University	6
Lignin	SSEU Chalmers Technical University	2
General evaluations, studies etc.	Flygfältsbyrån Engineering AB (Engineering company in the field of construction and infrastructure) ÅF-IPK (Technical consulting company) Arbetslivsinstitutet (Labor (environment) related research institute) IVL (Swedish Environment Institute)	4
Total	11	27

Table 19: R&D projects funded by the Ethanol Development Programme, 1993-1997
Source: (Östman, 1998: 45-46)

Ethanol vehicles

The heavy vehicle manufacturer SAAB-Scania was particularly active in trials of ethanol in vehicles. SAAB-Scania developed a preference for ethanol having carried out RD&D with both methanol and ethanol in diesel engines. This preference related to the relatively high energy content of ethanol, which was approximately 70% of its fossil fuel substitute. As is noted above, the energy content of methanol was approximately 50% of its fossil fuel substitute. This meant that ignition improvers were less expensive for ethanol use in diesel engines compared to methanol. SAAB-Scania ran single ethanol trials in Sweden from 1973, as well as more extensive ones in Brazil. Brazil had a vast demand for ethanol vehicles and was running long-term ethanol trials with inter-city buses (Swedish Commission for Oil Substitution, 1982: 103-104). The trial led to adjustments to the diesel engine to enable ethanol propulsion, such as a slight increase of compression and the use of ignition improvers to aid the ignition of ethanol (Larsson, 1997). In the early 1980s, SAAB-Scania initiated similar trials in Sweden. The short-term results of the Swedish trial showed no indication of increased engine wear. With regard to the emissions of ethanol in direct-injected turbo-charged engines, NO_x and hydrocarbon emissions were similar to diesel use while emissions of particulate matter were reduced (Swedish Commission for Oil Substitution, 1982: 103-104).

The SDAB was also experimenting with ethanol. However, in contrast to SAAB-Scania's bus trials, SDAB tested low blend ethanol in gasoline cars. The SDAB trial concerned two cars running on gasoline with a 7% ethanol blend (E7) for 2-3 years, and the results were positive (Swedish Commission for Oil Substitution, 1982: 88). The low ethanol blend influenced neither the drivability nor the ignition of the engine. As is noted in the methanol section (Carlsson & Nygren, 1994), ethanol enjoyed a 50% tax exemption from the gasoline tax from 1981 onwards. This tax exemption is not likely to have benefitted the SDAB

[56] In Swedish STFI is Skogsindustrins tekniska forskningsinstitut. In 2003 the research institute STFI merged with the Research Institute for Packaging, Packforsk, and was given a new name - STFI Packforsk AB. In 2009, it changed name once again to Innventia AB.

trial very much. Nevertheless, it benefitted the trials that followed, such as the 4% ethanol blend introduced by OK in the early 1980s outlined above.

The SSEU introduced increasingly serious ethanol vehicle trials. Their first trial involved two E95 buses at Örsköldsvik Buss AB in 1985, using the engine technology Scania developed in Brazil (Larsson, 1997). In parallel with the Örsköldsvik trial, the SSEU started running two additional buses in Gothenburg in 1986. Later these were transferred to Stockholm, and the greater Stockholm public transport company, Storstockholms Lokaltrafik (SL), which had previously experimented with alternatives, such as LPG, methanol and electric battery-powered buses (Sandén & Jonasson, 2005). Scania's engine technology was also used in these trials. The ethanol used in the trials was partly from the sulphate ethanol production plant and partly imported wine ethanol from France (Rehnlund & Van Walwijk, 2005).

In 1988, the SSEU decided that it was time to scale up the small-scale bus trials in Örnsköldsvik, Gothenburg and Stockholm. On SL's initiative a plan was made for a three-year trial with 30 ethanol city buses in addition to the two ethanol buses already running in Stockholm. The aim was to make a larger scale trial work and prove the potential for further emission reductions. Government support was easily gained since the trial was in line with current environmental politics. For the first two years of the project, SEK 27.6 million was provided by the Energy Agency (STEV), the STU[57] and the Swedish Transport Research Board (Transportforskningsberedningen, TFB), while SL contributed SEK 20.6 million. Based on these funds, 30 additional ethanol buses were introduced in 1990. The project leader, Charlie Rydén of SL, coordinated the project with a steering group that included representatives from SL, SSEU and the financers. While SL was responsible for the total ethanol user system, storage, distribution, security and maintenance, Scaniabussar AB produced and delivered the buses, Saab-Scania AB developed the ethanol engines and assisted with technical problems and SEKAB supplied the ethanol fuel and developed the fuel quality. A fuel pump adjusted to ethanol fuel was set up at the SL fuel depot to enable fuel distribution and an emission test facility was set up at SL to test the emissions. Additional emissions tests were run at the motor test centre ASB in Jordbro. The engine and technology used at the trial were slightly adjusted diesel engines referred to as second-generation Scania ethanol engines. A 2% fuel additive was added to enable ignition, as well as 3% denaturalizing components such as isobuthanol and MTBE. SEKAB built an installation for the preparation and management of the fuel in Örsköldsvik. In addition, SEKAB developed an ethanol fuel quality standard, which was not part of the official fuel standards (Rydén, 1994).

The popularity of ethanol was shown by the project funding by national authorities and by government tax exemptions. In June 1990, the government introduced a CO_2 tax on transport fuels. This was a new tax for regular fossil fuels, while ethanol and methanol were exempted (Finansdepartementet, 1990). At the end of 1991, E85 was given full tax exemption from the CO_2 tax and the energy tax (Riksdagen, 1991).

In 1992 the government set up a Biofuel Programme, which provided funds for additional ethanol initiatives (Sandén & Jonasson, 2005; Bucksch & Egebäck, 1999). Despite the name, the initial programme focus was on ethanol. The programme aim was fourfold. First, to develop, test and evaluate ethanol-related technology and systems. Second, to stimulate the participation of larger producers and users in trials. Third, to improve knowledge about the use, environmental potential and economy of ethanol in the long term. Fourth, to clarify the necessary conditions for a larger-scale introduction of motor alcohols. TFB, which shortly after became known as the Communications Research Board

[57] The Energy Agency and STU were merged into NUTEK (Swedish National Board for Industrial and Technical Development) in this period.

(Kommunikationsforskningsberedningen, KFB), managed the programme in cooperation with the Swedish National Board for Industrial and Technical Development (NUTEK), the Swedish Environmental Protection Agency (EPA) and the Luleå University of Technology. The programme ran from 1992 to 1997 with a government budget of SEK 120 million. In order to increase the success rate, a prerequisite for programme funding was co-financing and cooperation among project partners (KFB, 1994). Hence, for each project, the government would finance a maximum of 50% of the costs. The result was a total financial contribution to the programme, from government and programme partners, of SEK 315 million. A wide selection of alternative fuels gained funding (Bucksch & Egebäck, 1999), some of which are outlined in the section on biogas below.

Both the Örsköldsvik and the Stockholm ethanol bus trials gained continued funding within the Biofuel Programme. According to Larsson (1997), the success of the Örnsköldsvik project led to the preparation of a follow-up project 'Project Västernorrland' in 1993. The lead of the project was still the bus company Örnsköldsviks Buss AB. Additional key actors were SEKAB and Svenska Etanolbränslen AB,[58] which assisted with ethanol fuel storage and distribution, and the farmer-led company OLSAB,[59] which contributed the bio-based lubricants. Additional partners were KFB, Örsköldsvik's municipality and the County Administrative Board of Västernorrland. Important suppliers were Scania, which delivered the buses, and Akzo Nobel AB, which supplied the ignition improver Beraid. This project ran from 1993 to 1997. In 1993, four ethanol buses were added to the two already running. In 1996, two additional buses were implemented. The central aims of the project were: (i) to prove the maturity and reliability of ethanol bus technology; (ii) to prove that ethanol fuel could reduce emissions; and (iii) to develop adequate fuel compositions and standards for ethanol. The total project cost was SEK 8.24 million, of which KFB contributed SEK 2.77 million. The project partners paid the remaining expenses, in particular the local authorities. Unlike other trials, the eight ethanol buses running in Örnsköldsvik had large banners on their sides informing the public that they were running on environmentally friendly ethanol. In addition, the project partners experimented greatly. They used Scania buses with both old and new ethanol engine technology, different qualities of ethanol, lubricants and ignition improvers, which led to a succession of developments towards more environmentally sound practices. One example is the experimentation with the new ignition improver Beraid, which showed good environmental performance and became the main ethanol ignition improver on the market (Larsson, 1997). Additional valuable lessons were that ethanol adapted engine filters would avoid clogging and that higher quality pipes and engine parts would avoid engine wear caused by ethanol (Holm, 1997). Larsson (1997) indicated that trials in Stockholm and Örnsköldsvik shared many problems, such as clogged filters, and that the project partners sought cooperation between trials to resolve these.

The Örnsköldsvik project partners proved ethanol buses to be equally reliable as diesel buses. In addition, emissions reductions were positive, especially with regard to reductions of NO_x, particulates and CO_2 emissions. Nevertheless, NO_x emissions were not as low as in the Stockholm trial. A potential explanation for this was that Scania had optimized the engines for the ignition improver used in Stockholm, which was different from that in Örnsköldsvik. One problem was that new, unregulated ethanol emissions appeared, such as of

[58] SEKAB did not deliver the ethanol fuel, Svenska Etanolbränslebolaget AB did. SEKAB only mixed the fuel, checked the quality, etc. After 1995, however, SEKAB bought Etanolbränslebolaget and managed the delivery of the ethanol fuel.

[59] OLSAB (OK Lantmännen Smörjolje AB) was a cooperation between the oil distribution company OK and the Farmers' Lubricant Production company, Lantmännens Smöroljeproduction AB.

aldehydes. As in so many other trials, the main problem was the high cost of the ethanol fuel (Larsson, 1997). A project contribution was that experimentation with ethanol buses spread through a region wide collaboration, which led to trials with ethanol buses in the cities of Umeå and Sundsvall (Karlsson & Jalmby, 2007). The goals set for the trial may not have been reached completely, but improvements were made in relation to reliability, emission reduction and fuel quality.

In the Stockholm trial, a second phase, 1992-1993, was financed by SL and TFB/KFB alone at a total cost of SEK 5.1 million. The results of the projects were positive. Like Örnsköldsvik, the project partners stated that ethanol buses were as reliable as conventional diesel buses, and that the maintenance costs were comparable. A new problem was the vinegar smell (Rydén, 1994). Holm (1997) noted that the participants in the Stockholm trial considered this a problem, but not the participants in the Örsköldsvik trial. According to the managers of the Stockholm trial, the problem appeared when the buses were equipped with catalysts. The project partners introduced more advanced catalysts, which reduced the smells and the complaints (Holm, 1997). The project contributed to a greater awareness of ethanol as an environmentally friendly fuel for city buses. Emissions of NO_x, CO, HC and particulates were very low with the second-generation Scania engine. As a result, Scania started developing a third-generation engine aiming for lower emissions. Other emissions, such as aldehydes, polyaromatic hydrocarbons and mutagens components, were also low and confirmed previous tests and observations. The total cost of the two phases of the Stockholm project was SEK 53 million, of which SL contributed SEK 23 million and the government SEK 31 million. Once the KFB funding ended in June 1993, the buses kept running in regular city bus traffic (Rydén, 1994).

In addition to the Örnsköldsvik and Stockholm trials, a field trial took place in Skaraborg County between 1993 and 1996. The County Administrative Board of Skaraborg, the farmers' interest group Västsvenska Lantmännen (more recently known as Lantmännen Odal) and the Regional Traffic Authority of Skaraborg (Läns Trafiken) wished to start a large scale trial with ethanol buses to reduce inner city pollution. After applying for grants from the Biofuel Programme in 1992, KFB contributed SEK 3.15 million of the total budget of SEK 7.3 million. The Regional Traffic Authority in Skaraborg was the main leader of the project. Both the regional authority and the municipalities of Skövde and Mariestad were involved, as the co-owners of the Traffic Authority. Other actors were the public transport companies, Swebus in Skövde and Mariestads Busstrafik AB, which ran the buses, and SEKAB and Svenska Etanolbränslen AB, which distributed the fuel. A trial with 15 buses was started in Mariestad and Skövde, of which 10 were converted diesel buses and five were new third-generation Scania buses. In addition, an infrastructure was set up to provide maintenance and ethanol fuel, training for the personnel and public information. The goal of the ethanol trial was threefold: an environmental goal involving emissions reductions, a reliability goal and a cost efficiency goal. In 1995, the project period ended and the project partners applied for an extension of one year. The budget for the additional year was SEK 2.55 million of which KFB granted SEK 639 000. With regard to the different goals of the project, the first goal, on environmental improvement through emission reduction, was reached according to the results from emissions tests. The second goal, on reliability, was not reached due to the high maintenance needs of the fuel system and various engine problems. Nevertheless, reliability increased during the project due to adjustments to ignition improvers and lubricants. Third, with regard to the costs, there was a saving of SEK 2.83 per 10 km from using ethanol instead of diesel, if calculating the costs of emissions, according to the Economics Department at Gothenburg University (Berg, 1997a).

On top of the technical problems, a more persistent problem for ethanol experimentation was the price of ethanol, which almost doubled during the 1990s (Ekelund, 1997). Part of the expense was a result of the heavily monitored distribution of ethanol. The ethanol buyer had to seek permission from the Swedish Medical Products Agency (Läkemedelsverket). In addition, authorities monitored ethanol quality, quantity and delivery routes, including sender and receiver. In 1997, this meant extra costs of SEK 0.06 per litre ethanol.

A more serious cause of the increase in cost of the ethanol trials was Sweden's entry into the EU in 1995. EU regulations dictated particular tolls and fees for ethanol imported from EU countries, but also for the sulphate ethanol from Örnsköldsvik. Hence, both imported and domestic ethanol became more expensive. In the Örsköldsvik project, a collaboration with a London-based company led to a lower price for wine ethanol in the autumn of 1995 (Larsson, 1997). In addition, EU membership meant that the government had to replace the general tax exemption for high blend and pure ethanol with EU biofuel temporary tax exemptions for pilot projects only. The government granted temporary tax exemptions for some Swedish biofuel trials in 1996 (Kristenson, 1997b; Ekelund, 1997). However, government promises of continued ethanol tax exemptions for high blends and future tax exemptions for ethanol low blends seemed to placate most actors (Carlsson & Nygren, 1994; Persson & Åsbrink, 1997). This promise contributed to continued ethanol experiments in Stockholm (Holm, 1997), which resulted in an ethanol bus fleet of 300 buses by early 1997. However, there was no relief from the EU price increases for the Skaraborg trial, which did not recover after the trial stopped in 1996 (Berg, 1997a).

Inspired by the success of the early ethanol bus trials and the commitment of local authorities, the idea of setting up a trial with ethanol trucks emerged. The motives for this trial were fuel security in case of future oil shortages, and a reduction in CO_2 emissions. Discussions on the possibility of an ethanol truck trial started between Volvo, the transport company Bilspedition/BTL Sweden, the recycling company SRV, the municipality of Örsköldsvik and TFB/KFB in 1991 (Ekelund, 1997). During these negotiations, Volvo Trucks, Chalmers Technical University and TFB/KFB developed a template for a seven-litre diesel engine adjusted for ethanol fuel with added ignition improver (Kristenson, 1997a). The project was named Svenol and had a two aims. First, to test and evaluate the technical, environmental and socio-economic benefits of running ethanol trucks in densely populated areas. Second, to evaluate the potential for the commercialization of ethanol trucks. In 1995, at the start of the trial, additional partners joined SEKAB and the SSEU to assist with the trial, such as Falun municipality, the oil distribution company OK, and the bio-based and farmer-owned lubrication company OLSAB. The project gained its main funding from the KFB and the Swedish Council for Work Life Research,[60] but there is no information on the amount of funding. The project partners selected Mats Ekelund from the consultancy company Strateco Utvecklings AB as the project leader. The idea was to introduce five trucks at once and an additional four at a later stage. While many companies were interested in participating in the project, most withdrew once the economic costs became clear. Hence, only four trucks were introduced in 1995, after being delivered by Volvo at some discount. BTL Sweden ran two of the trucks in the town Växjö. The recycling company SRV in the region Södertörn ran one and Örnsköldsvik municipality ran a garbage disposal truck. In addition, Volvo delivered three heavy vehicles in 1997. Falun municipality bought two of these, one garbage disposal truck and

[60] This council, called 'Rådet för arbetslivsforskning' in Swedish, was an authority that gave support for research and development within the area of working life and has since 2001 been replaced by the Swedish Council for Working Life and Social Research and Vinnova.

one street sweeping vehicle. Örsköldsvik municipality bought the third vehicle. The vehicles worked satisfactorily without inconvenience or unusual interruptions compared to diesel vehicles. Only two problems occurred during the trial. First, in November 1995, three of the four vehicles had their fuel filters clogged. Second, in the cold months, the vehicles had starting problems and were slow during their first hundred meters compared to diesel vehicles. After the ethanol fuel was upgraded in 1997 and the drivers had learned to keep the vehicles idling before driving away, these problems were reduced. A positive outcome of the use of the ethanol trucks was that the experience of the vehicles as much more spirited compared to the diesel vehicles. Like the other ethanol projects, the greatest environmental gains were cuts in CO_2 emissions, provided the production process limited the use of fossil energy. Moreover, NO_x emissions were only 30-50% of diesel emissions, unregulated emissions were much lower than those of diesel and particle emissions were lower than from diesel. The particles caused by ethanol were different and seen as potentially less harmful than those from diesel (Ekelund, 1997). One of the barriers for the project was the environmental tax on vehicles, which was applied to all vehicles that were not classified as environmental class 1 vehicles. There was major resistance to this tax, which punished projects like Svenol that aimed to improve the environment. Eventually, in 1996 an exemption from the environmental tax was given to pilot projects. This meant that the first four vehicles in the Svenol project had to pay a tax of SEK 65 000 per vehicle (Ekelund, 1997; Kristenson, 1997a). As in the bus projects, the Svenol project partners saw the ethanol price as the biggest problem, and the Svenol project suffered temporarily from adaptation to EU tax rules (Ekelund, 1997). The project concluded that ethanol truck technology was ready for commercialization and that there was an interest from companies in using ethanol if the government could guarantee sufficient ethanol at a lower price. In 1997 the project partners asked the government for continued funding in order to evaluate the long-term use of ethanol in trucks (Ekelund, 1997).

Returning to the Biofuel Programme, KFB realized early on that the implementation of pure fuels would take time. Hence, the promise of low biofuel blends which had been strong among methanol proponents in the 1970s reappeared. The main argument behind this development was the need to deal with the environmental problems resulting from conventional fuels, in particular CO_2 emissions, in the short term (KFB, 1994). The SSEU introduced the idea of starting trials with ethanol mixes in diesel in 1992. Alongside the focus on CO_2 reductions, SSEUS's arguments for the trial were to reduce the import of fossil fuels and stimulate domestic production of bio-ethanol. A more general goal, similar to other alternative fuel experiments, was to gain sufficient experience of implementing fuel mixes and to facilitate the shift to pure fuels in the future (Berg, 1997b). Initially, various Swedish Technical Universities ran tests in laboratories. They concluded that a 15% ethanol mix in diesel was the maximum if the engine was not to require big changes (Granvik, 1997). KFB granted the SSEU funding and introduced a first phase trial with four vehicles in December 1995. In 1996, the SSEU added 15 vehicles to the trial (Berg, 1997b). The locations for the trials were Lidköping, Värö bruk, Sollefteå and Stockholm, where low blend ethanol fuel pumps were set up. One pump was set up by OK, another by SSEU and the rest by the people running the vehicles. While Rolf Berg at the SSEU was running the project, actors cooperating in the project were the vehicle hosts, the fuel distributors (at first SOAB in Gothenburg, later SEKAB) and the vehicle distributors. The fuel was a mix of ethanol, diesel and the emulgator Dalco imported from Australia (Berg, 1997b). The emulgator was used to prevent separation of diesel and ethanol, which was crucial for successful use in diesel engines. However, the effect lasted only for a limited time; approximately 90 days for a 15% ethanol mix (Granvik, 1997). The vehicles were diesel cars, buses or trucks. Most drivers were happy with the vehicles, with the exception of the drivers transporting heavy lumber who complained that acceleration had been lost (Granvik, 1997; Berg, 1997b). There was also some extra maintenance, such as frequent changes of fuel filters to avoid clogging. According to Egebäck at Luleå Technical University, however, the emissions were similar to those from normal diesel use. The only radical difference was the reduction in small particles emission. The fuel was given different names at the different test sites, such as Etamix or Diesohol. While emission reduction and the properties of the fuel could be improved, in particular the emulgators, the project leaders saw this option as a good way to introduce ethanol as a future fuel (Granvik, 1997).

As a result of the experimentation with ethanol in diesel engines in buses and trucks, a Swedish standard appeared in 1997: the standard for alcohol used in diesel engines, SS 155437 'Motor fuels – Fuel alcohol for high-speed diesel engines'. Although the standard was developed in response to the need for a standard for ethanol use, it used the term 'alcohol', which meant that methanol was part of the standard as well (Rehnlund & Van Walwijk, 2005).

According to Brandberg et al. (1994), environmental arguments played an increasingly large role in the implementation of alternative fuel vehicles. Not only national environmental goals and the problems reaching them, but also the United Nations Framework Convention on Climate Change and Agenda 21 on sustainable development provided incentives for the introduction of environmental vehicles and FFVs. According to the Agenda 21, the UN programme for sustainable development in the 21st century, all UN member states, municipalities and societal groups were bound to work towards the long-term goal of ending poverty and the threats to the environment. Brandberg et al. (1994) used the successful introduction of alcohol-gasoline FFVs in the US as an example of what FFV's could mean for Sweden. In the US, the various environmental standards introduced resulted in the introduction of about 10 000 FFVs running on E85/M85 by the end of 1993. One of the main conclusions by Brandberg et al. was that comprehensive US emissions tests showed that FFVs reduced health and environment harming emissions considerably, such as nitrogen oxides (40% reduction with M85), the formation of ozone (50% reduction with M85) and the risk of cancer (more than 50% reduction with M85). The second conclusion was that the main bottleneck, cold start problems, was under investigation and already had potential solutions, such as engine heating below -15°C. Third, FFVs are a relatively cheap alternative that do not affect the use of the car. Fourth and finally, while methanol from fossil sources was the main fuel used in FFVs abroad, Swedish biomass resources together with FFV technology would enable a transition towards bio-based alcohols.

Brandberg et al. (1994) saw great potential for SAAB and Volvo to supply FFV technology to the Nordic and eventually the European market. These companies were ready to present a prototype within 12 months and a demonstration fleet within 24-36 months. This conclusion was probably related to the great experience that both Volvo and SAAB had in relation to methanol vehicles and the use of high blend alcohols in gasoline. Moreover, according to Brandberg and Sävbark (Brandberg & Sävbark, 1994: 33, 38), Volvo had participated in one of the early experiments developing FFV technology in the US and Saab had already developed certain FFV technology. Moreover, Brandberg et al. (1994) pointed out that this would be a long-term project, and so the automobile industry would not need to worry about economic return. The only worry, according to them, was the oil companies. In the US they had not been cooperative in distributing the fuel despite the use of methanol from fossil resources. Ecotraffic presented a model for FFV introduction in Sweden. The model reserved the years 1994-1997 to resolve the cold start problem, and thereafter three phases would follow. First, in 1998, Ecotraffic suggested the introduction of 500 FFVs in the big cities. Second, in 2000, the trial would expand geographically with the successive introduction of more than 800 cars per year. Moreover, Ecotraffic suggested a long-term change programme for the use of alcohol fuel. Third, Ecotraffic expected a general market implementation of FFVs in 2005 (Brandberg, Johansson, & Sävbark, 1994). According to Kristenson (Kristenson, 1997b), the introduction of FFVs able to run on both gasoline and ethanol meant that the Catch 22 of no distribution infrastructure, no cars, and vice versa, was no longer a barrier to ethanol introduction.

According to Kristenson (1997), the FFV plan by Ecotraffic was of interest to the SSEU, which wanted to expand the ethanol market. According to Sandén and Jonasson (2005), there was a particular urgency for new ethanol markets due to the privatization of public bus companies in 1992, which led to limited means to expand the ethanol bus trials. Kristenson (1997) reported that interest from oil distribution companies and car producers was almost non-existent. However, the FFV project managed to take shape anyway as a result of the many alternative fuel contractors that saw an opportunity in the automobile sector after losing their jobs at the bus companies (Sandén & Jonasson, 2005). According to Kristenson (Kristenson, 1997b), Charlie Rydén, responsible for the ethanol bus trial, researched the option of FFVs and Jan Lindstedt at SSEU asked the local Ford dealer in Örnsköldsvik, Per Carstedt, to find a vehicle manufacturer interested in developing an ethanol FFV. Carstedt did not find any European manufacturers interested in supplying FFVs, despite the argument in Brandberg et al. (1994) that both Volvo and Saab were interested and had the necessary technology to introduce an FFV demonstration fleet. A survey among 23 car manufacturers carried out in the mid-1990s explains the resistance of the domestic vehicle industry:

> Technology is not a problem when it comes to alternative fuels and biofuel. The problem is availability [...] Neither SAAB nor Volvo will invest in alternative fuels if there is not a market. There is also a sceptical attitude to 'political solutions' and the use of biofuels built on an artificial basis. A viable long-term prospect is a prerequisite for introducing alternative fuels. [...] To sum up, you could say that the introduction of a new fuel takes longer than to develop new engines (Birath & Pädam, 2010: 10)

The quote indicates the lack of technical bottlenecks when it came to ethanol vehicle development. Instead, car manufacturers indicate that the barrier to development was a lack of ethanol fuel infrastructure and genuine market demand. This indicates that the Catch 22 of no cars without fuel infrastructure and no fuel infrastructure without cars was still a problem.

Nevertheless, the lack of interest by the domestic vehicle industry did not stop the SSEU's plans. Instead, Carlstedt's knowledge of recent developments in California and their mass production of Ford FFVs led to the import of three Ford Taurus FFVs to Örnsköldsvik in 1994. One car started running for SSEU, another for Örnsköldsvik municipality and the last one for SEKAB (Svensk EtanolKemi AB). The FFVs worked perfectly and a variety of municipalities and companies showed an interest in the technology, which led to a scaling up of the project. Charlie Rydén became the project leader; KFB joined with funds and OK facilitated the ethanol distribution. OK was the only oil distribution company interested in the ethanol alternative (Kristenson, 1997b). As a second step in 1995, the project partners leased out 50 additional FFVs to contracted customers in Örnsköldsvik. In parallel, SEKAB and OK set up three fuel pumps, one each in the cities Örnsköldsvik, Stockholm and Karlstad. In a third step in 1996, the project partners organized a PR tour by train together with an environmental organization, the Natural Step Foundation. On this tour they offered every local authority or business an E85 pump at their local OK fuel station if 10 FFVs were bought (Sandén & Jonasson, 2005). To benefit from the temporary tax exemption for biofuel demonstration projects, the project partners had to lease the FFVs. The inability to sell the FFVs with tax benefits set limits on expansion (Birath & Pädam, 2010). Nevertheless, the initial expansion of the fleet was successful. In 1997, Sweden had as many as 300 FFVs and about 30 filling stations providing E85 (Kristenson, 1997b; Pädam, 2009). The expansion of ethanol pumps at OK filling stations was easier than expected. Due to a decline in the variety of gasoline types provided at fuel stations, most filling stations had a free tank that they could use for ethanol. Nevertheless, in both the south-east and the north of Sweden, E85 distribution was generally absent. The SSEU and the FFV project arranged the import and distribution of Ford FFVs. All the FFVs were green and had stickers indicating the use of renewable ethanol fuel. Ford had developed the FFV models to run on methanol in the US, and it was only at a later stage that Ford offered FFV models that were optimized for ethanol use in Swedish conditions. The environmental organization the Swedish Society for Natural Conservation (Svenska Naturskyddsföreningen) gave these vehicles the consumer product label 'Good environmental choice' (Bra miljöval) provided they were run on at least 95% E85 fuel. With regard to the results of the FFV trials, there were some worries that the vehicles would not be able to overcome the cold start problems in such a cold climate. The project partners solved this by adding more gasoline during the winter or using an engine heater, but continued to search for better solutions. The drivers of the FFVs considered the drivability equal to that of gasoline vehicles. If more ethanol was added to the blend the vehicle was experienced as more peppy but more fuel consuming. The emissions tests showed low emissions for both gasoline and ethanol use in the FFVs. However, a downside was that the large US vehicle design used more fuel than the average European brand. Women in particular complained about the environmental impact of the large cars and asked for smaller cars and other brands of FFVs. The ethanol fuel used for the FFV project was domestically produced ethanol from wood in Örnsköldsvik. Examples of the companies that introduced FFVs to their car fleets were the car rental company Budget and McDonalds (Kristenson, 1997b).

Not only the FFV fleet was expanding, other vehicle fleets were too (see Table 20). Despite the budget cuts at municipalities and bus companies in the early 1990s, the heavy vehicle ethanol niche did not die out. According to Brandberg and Sävbark (1994), a commercial niche market was created for ethanol buses. According to data presented in Sandén & Jonasson (2005), 300 buses and 24 trucks were running on ethanol, mainly on E95 but also on E15, in 1996.

Type	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Buses	2	4	4	6	6	38	38	38	59	59	59	300	300
Trucks											4	4	24
FFVs										3	53	303	300
Total	2	4	4	6	6	38	38	38	59	62	116	607	624

Table 20: Number of ethanol buses, trucks and FFVs, 1985-1997
Source: for buses and trucks in text, for FFVs see Pädam (2009: 19).

According to Sandebring (2004), the total amount of ethanol sold in Sweden in 1995-1997 was 26.000 m^3. In the bus and FFVs trials up to 1997, 10 000–15 000 m^3 of ethanol was exempted from the energy tax and the CO_2 tax. The government delivered the tax exemption within the framework of the EU pilot exemption (Rehnlund & Van Walwijk, 2005). After a Swedish negotiation with the EU, all E85 was exempted for a five-year period from 1997 (Kristenson, 1997b; Ekelund, 1997). At that time, the tax exemptions enabled an ethanol price equal to that of gasoline. However, the ethanol actors expected an increase in the ethanol price (Kristenson, 1997b). One reason was the limited ethanol supply, which needed to meet the demand of different markets. Of the 91 000 tonnes of bio-based and fossil industrial ethanol used outside the food sector, Sweden produced only 10 000 tonnes and the transport sector used only 6000 tonnes (Ekelund, 1997). Domestic production would not be able to serve an expanding FFV fleet. Moreover, the imported wine ethanol from the South of Europe that fed the ethanol bus fleet could not be expanded either (Kristenson, 1997b). The price of wine ethanol was relatively cheap, but this was only due to great subventions by the EU, which according to Ekelund (1997) corresponded to SEK 20-30 per litre. Hence, it was highly dependent on the agricultural politics of the EU and not considered a sustainable long-term option (Kristenson, 1997b; Ekelund, 1997).

The limited supply and high cost of ethanol fuel was not only a threat to the future development of FFVs and heavy ethanol vehicles, it is also likely to have been a barrier to the development of low blends of ethanol in fossil fuels. As is outlined above, OK had experimented with a 4% blend in the 1980s in connection with the running of the small-scale crop ethanol plant by Agrienergi. According to SEKAB (2008a), OK, which merged with Q8 to form OK/Q8, started blending 10% ethanol in the gasoline in 1997 (SEKAB, 2008a). It is likely that the OK/Q8 initiative went hand in hand with KFB's (KFB, 1994) interest in using ethanol low blends. The fact that OK was a cooperative with a farmers' organization among its owners and founders (OK, 2001) is also likely to be a contributory factor to OK's involvement in the low blend and pure ethanol experiments since the 1980s.

As is noted above, other oil distribution companies were not at all interested in ethanol. As late as 1997, Bart van Holk, CEO of the fuel technical programme of the (Swedish) Shell Group argued that LPG (motorgas) and natural gas were the best fuel alternatives to gasoline and diesel. Ethanol, however, was a far too expensive means to reduce CO_2 emissions (Miljörapporten, 1997c). This position was not surprising, given that Shell was part of a strong international fossil fuel actor.

7.2.2. Ethanol SNM analysis, 1980-1997

Ethanol 1973-1997	1973-1979	1980-1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Net-work				SSEU														
																Environmental Vehicles/EU		
Trials	Saab-Scania bus																	
		SDAB 2 E7 cars																
					Wheat ethanol plant													
					Ethanol import													
						Sulphate ethanol for vehicle fuels												
						2 buses Ö-vik								6			8	300 buses Swe-den
							2 buses Gtb											
									2 buses Sthlm		32 buses							
														15 buses Skaraborg				
																Svenol 4 trucks		7
																4 - 22 vehicles E15 diesel		
															3 FFVs	53	303	300
															E85 pump			30
					E4 OK													E10 OK/Q 8
R&D														R&D program				
					Chematur: Strong acid hydrolysis													
					SSEU: Weak acid hydrolysis										SSEU: Weak acid			
					LTH: Enzymatic hydrolysis										LTH: Enzymes			
															Chalmers: Fermentation			
															SSEU: Lignin			

Table 21: Ethanol development, 1973-1997

Network actors	Biofuel	Expectations	Key experiments	Learning	Socio-technical configurations
Crop ethanol network driven by farmers' cooperations. Cellulose ethanol network driven by SEKAB (chemical industry and paper and pulp industry) and the SSEU foundation (SEKAB, municipalities, farmer organizations, universities). The networks merge over time. Additional key actors are Saab-SCANIA and the fuel distributor OK.	Crop and cellulose ethanol production and use as low and high blend/ pure	Ethanol cheaper and more environmentally friendly than methanol. Creating market opportunities for agricultural and chemical industry. Crop ethanol as a short-term alternative and cellulose ethanol as a more environmental and cost-efficient alternative in the long term. Shortcomings in agricultural sector and increasing environmental concern stimulate expectations	Difficulties in realizing production lead to focus on ethanol market creation. Successful ethanol buses in Örnsköldsvik and Stockholm, but financial barriers to further expansion lead to FFV introduction at end of period.	Positive technical and a few social lessons lead to expansion of bus and FFV fleets as long as financial means are provided.	Temporary wheat ethanol production and development of cellulose ethanol processes. However, realization of bus market niche in early 1990s. Implementation of FFV fleets and low blend use based on imported ethanol. Related infrastructure for distribution and storage in place as well as standards, which indicate increased niche stability.

Two *networks* drove ethanol development in this period: a crop ethanol network and an advanced cellulose ethanol network. The crop ethanol network was initially driven by farmers' organizations, which ran a small scale wheat ethanol plant and stimulated ethanol use in the 1980s. SEKAB, a company owned by the chemical and paper and pulp industry, initiated cellulose ethanol activities, produced sulphate ethanol and imported ethanol for conventional ethanol trials. SEKAB set up the cellulose ethanol network by means of the SSEU in collaboration with many municipalities, industry and a farmers' organization with both forestry and agricultural interests. The SSEU played a key role in advancing cellulose ethanol R&D in collaboration with universities. Additional key actors that contributed to field trials in collaboration with both the crop and cellulose ethanol networks were: Saab-SCANIA, which developed ethanol buses, and the fuel distribution cooperative OK, which distributed high and low ethanol blends, various (mainly public) fleet owners and Ford facilitated FFV vehicle trials. The fact that the networks prioritized the creation of an ethanol market and collaborated in reaching that goal indicates the existence of a common ethanol network with relatively good alignment, despite the separate production interests. Both network width and alignment increased over time.

The early actor *expectations* that propelled ethanol experiments in the early 1980s were that use of domestically produced crop ethanol would create market opportunities for the agricultural and chemical industry and offer a mature bio-based technology that was cheaper and reduced more emissions than methanol on a short-term basis. The high oil price and problems in the sugar industry were external factors that are likely to have stimulated these early expectations. At a later stage, growing environmental concerns played a greater role in creating potential business opportunities and reaching environmental targets. The network actors expected ethanol to be suitable for high and low blends in diesel and gasoline vehicles. In the medium to long term, cellulose ethanol actors expected advanced cellulose ethanol to be more economically efficient and environmentally friendly than conventional ethanol and to contribute to new market opportunities for the wood and chemical industry. This separation in the actor networks meant that the different groups voiced expectations with regard to their technology only. However, this was not a problem since the crop and cellulose ethanol expectations were not in conflict due to their different level of maturity.

The experiments involving ethanol use in vehicles were successful, generating positive *learning processes* that reinforced the expectations and contributed to successful niche development. Examples of this were: first, the bus niche that through experimentation overcame problems and advanced engine and fuel technology; second, the involvement of users to identify and resolve problems such as exhaust smells; and, third, the sharing of lessons across projects in order to develop standards. However, increased fuel prices and budget cuts in public transport companies led to a pause in niche expansion in the 1990s and indicate the importance of financial support for market expansion. This led to a move of entrepreneurial efforts to the implementation of FFVs. Unlike the success of experiments with ethanol use, the experiments with ethanol production did not meet expectations. Although a short-term crop ethanol pilot ran successfully in the 1980s, insufficient actor commitment resulted in a failure to continue and scale-up production despite government support. In addition, the expectations of implementing cellulose ethanol in the medium- to long-term perspective proved unrealistic. Despite shortcomings in the case of advanced ethanol, expectations were only slightly adjusted and financial support continued.

The above niche processes contributed to temporary crop ethanol production and import alongside domestic sulphate ethanol production, a bus market niche and FFV fleets with related distribution infrastructure and standards. By the mid-1980s, ethanol had surpassed methanol and become the largest alternative fuel.

7.2.3. The development of an alcohol/ethanol discourse, 1980-1997

When the first oil crisis hit Sweden in 1973 there were two mature ethanol technologies available: sulphate ethanol and food crop ethanol. It is surprising that ethanol was not considered as interesting as the immature methanol technology. One explanation for this was that ethanol actors did not have a coalition of powerful lobbying actors related to the vehicle or fuel sector at the time. The methanol coalition was led by a vital player in the transport sector, Volvo. Moreover, the government was an additional key actor that took an increasing lead in methanol development. Government support was probably linked to the fact that Volvo was a central player in Swedish industry and thus the Swedish economy. Together, these actors contributed to a discourse that presented methanol as a cheaper and more flexible option than ethanol due to its ability to use a great variety of feedstock.

When fear of a second oil crisis emerged in the mid-1970s the oil substitution discourse increased in urgency, and other fuel alternatives such as ethanol appeared on the policy agenda. As is outlined above, there were two crucial developments. First, the 1978 report by the Energy Commission that stressed the need to include other alternative fuels on the policy agenda. Second, the energy policy compromise following the nuclear energy debate in 1979 that led to increased funds for bio-based alternatives in particular. However, without a proactive ethanol coalition and discourse that successfully linked up with general discourse developments there would have been no ethanol development.

The creation of an ethanol coalition and related discourse was fed by positive experience of the use of crop-based ethanol abroad, in Brazil and the US among other locations, and, more importantly, by a reaction to the increasing inefficiencies of the Swedish agricultural industry. These inefficiencies were a result of agriculture policy. One reaction to these inefficiencies was an announcement by the Swedish sugar industry of the closure of a production plant. The sugar farmers felt threatened and started protesting against the planned closure. The interest in maintaining sugar beet cultivation and farmers' livelihoods in general led to the development of an ethanol coalition represented by the farmers' organizations (Svenska Lantmännens Riksförbund, SLR), the Agricultural Ministry, the oil distribution company, OK, and the Centre Party (Jordbruksdepartementet, 1980; Motoralkoholkommittén, 1986a). As is noted above, they all represented farmers' interests – even OK, a cooperative oil distribution company with strong influence of automobile interest organizations and farmer organizations (OK, 2001).

Alongside the argument that ethanol production from crops would sustain farmers' livelihoods, the ethanol coalition linked the ethanol discourse with the contemporary oil substitution and environmental discourses. The result was an ethanol discourse that ethanol was better than methanol at reducing negative impacts on the environment and substituting for oil since it relied on domestic and bio-based feedstock and a mature technology. The ethanol coalition acknowledged that the prevailing price of methanol from natural gas was 30% cheaper. However, it argued that crop-based ethanol would become cheaper since the natural gas price, and thus the methanol price, would rise along with the oil price in case of a new crisis. In addition, calculations on the expected price of bio-methanol in the long term showed that crop-based ethanol would become equally cheap (Jordbruksdepartementet, 1980). The majority, particularly the government, still argued that methanol was the best option. However, among the growing oil substitution discourse that increased the urgency for a short term fuel alternative, methanol coalition actors showed increased acceptance of other fuel alternatives such as ethanol. This was visible in the report by the oil substitution commission (Swedish Commission of Oil Substitution, 1980), led by pro-methanol actors such as SDAB, which accepted ethanol use as a complement to fossil methanol in low-blends until the bio-methanol option was mature. However, when it came to pure alcohol use, ethanol was excluded because methanol and ethanol were only compatible in small fuel mixes.

In 1980, there was discussion about the use of food crops for fuel internationally and in Sweden (see Jordbruksdepartementet, 1980). The Social Democrat Prime Minister, Olof Palme, feared negative consequences for the poor in the world if food was used for fuels. At an international conference in Ottawa, Canada, he stated: 'The scene is set for direct competition between the rich minority, which owns the world's 315 million cars, and the poor parts of humanity that fight to get sufficient food to survive' (Energimagasinet, 1980: 51, translated by the author). However, the debate on food versus fuel was limited in Sweden during this period and the ethanol coalition managed to push away these concerns by arguing for the use of damaged food crops, and later for the use of surplus crops, for ethanol production (Jordbruksdepartementet, 1980; Motoralkoholkommittén, 1986a).

In parallel with the development of the agriculture-based ethanol discourse, the chemical company, SEKAB, which managed sulphate ethanol production, sought additional markets. In 1983 a coalition of SEKAB, the Federation for Swedish Farmers (Lantbrukarnas Riksförbund, LRF), representing both agrarian and forestry interests, and municipalities around the city and region of Örnsköldsvik set up the Foundation for Swedish Ethanol Development (SSEU) to explore the potential of cellulose ethanol as a vehicle fuel. The SSEU became the main coalition leader for cellulose ethanol, with support from the bus producer Saab-SCANIA, which had interests in improving the ethanol engine technology developed in Brazil (Sandén & Jonasson, 2005). Some of the initial promise of the ethanol discourse in 1980 was that cellulose ethanol would be mature within 10 years (Jordbruksdepartementet, 1980). The SSEU was also part of the crop ethanol coalition and argued for a crop ethanol production plant (Jordbruksdepartementet, 1980; Motoralkoholkommittén, 1986b; Näringsutskottet, 1988). However, it expressed a preference for cellulose ethanol, arguing that mature grain-based ethanol should be used as a bridging technology for the more energy efficient, and thus increasingly oil substituting and environmentally friendly, cellulose ethanol (Sandén & Jonasson, 2005).

While the new ethanol coalition emerged in 1980, including farmers in the south and sulphate ethanol producers in the north, the methanol discourse still dominated the alternative fuel scene. This was seen in the government funding that still gave priority to methanol despite a policy directed towards broader alternative fuels. However, lobbying activities by the ethanol coalition resulted in a government grant in 1981 for the construction of an ethanol plant (see: Statens energiverk, 1986). In the same year, the government granted an ethanol tax exemption, which followed the decision on a methanol tax exemption one year earlier (Industridepartementet, 1983).

With increased attention on biofuels as an additional means of oil substitution alongside bioenergy, a debate emerged about the biomass route that would lead to the most efficient oil substitution (Fallde, Flink, Lindfeldt, Pettersson, & Wetterlund, 2007). An example of biofuel opponents was the THE, as is mentioned in the methanol section. Nevertheless, promoters of alcohol fuels, in this case the Motor Alcohol Committee, managed to fend off the energy efficiency argument by connecting the alcohol fuel discourse with both the oil substitution discourse and the growing environmental discourse:

> [...] the greatest oil substitution would be achieved if the energy forest were used as fuel for the production of electricity or heat. The oil substitution would be considerably lower if the energy forest were used as feedstock for the production of motor alcohols instead.

> Energy efficiency is not essential for choosing the most appropriate use of future energy forest cultivation. In different contexts it has been emphasized that the very great dependency on oil products in the transport sector creates problems for society. In the directives for this investigation, for example, the future security of supply in different crises and the environmental problems that oil use in the transport sector result in have been stressed. Therefore, there can be reasons for using domestic and environmentally friendly raw materials as propellants despite the relatively limited oil substitution. (Motoralkoholkommittén, 1986a: 97; see also Fallde et al., 2007, translation by the author)

The above quote and statements by the SDAB (1982) show how biofuel proponents started to include more environmental arguments for the development of bio-based and alternative fuels with their oil substitution arguments. This increased support for the ethanol discourse. Examples of policy measures that reflect this increased support were the recommendation of the Swedish Commission on Oil Substitution (1982) to use low ethanol blends (2-5%) in gasoline as a way to aid methanol introduction, and the ethanol tax exemption in 1981 that followed one year after the methanol exemption (Industridepartementet, 1983). This went hand in hand with the decision of the government to support crop ethanol production in 1981 and the choice of the farmer-based oil distribution company OK to start distributing a low ethanol blend in its gasoline (Statens energiverk, 1986). Hence, while the methanol option was still dominant and methanol coalition actors still argued that ethanol was much more expensive and not suitable for large-scale and long-term oil substitution, ethanol gained in acceptance as a low blend alcohol fuel. This development was part of the transition of the methanol discourse into an alcohol discourse as described in the methanol section.

The strongest coalition actors behind the crop ethanol plant, the farmers, faced increasing surplus wheat production and lobbied for continued support for ethanol production in a large-scale follow-up plant. In addition, the coalition managed to link the ethanol discourse with contemporary debate on the replacement of the toxic lead additive in gasoline introduced within the environmental discourse. They presented ethanol as a mature bio-based fuel that, unlike methanol, could substitute for lead in gasoline at once. This led to yet another investigation of ethanol by the Motor Alcohol Committee, carried out by seven parliamentarians (Motoralkoholkommittén, 1986a), but a large scale implementation of motor alcohols was not recommended. According to the new alcohol discourse, they did not choose between methanol and ethanol based on the argument that there was not yet sufficient grounds for this decision. This indicated the dominant position that the alcohol discourse had gained. According to the Committee (Motoralkoholkommittén, 1986a), the reason for not implementing alcohol fuels was the decline and stabilization of the oil price, which made alcohol fuels uncompetitive. The Committee advised against supporting the construction of the large-scale ethanol production plant the ethanol coalition had been lobbying for. Nevertheless, the Committee promoted the ethanol alternative due to its potential to serve as an emergency fuel based on domestic and renewable feedstock that could be mobilized in the short-term. Hence, based on this emergency argument, the Committee recommended pure ethanol fuel trials (E95) in diesel vehicles as well as further research on cellulose ethanol production. The focus on pure fuels in diesel vehicles was also motivated by the short-term environmental benefits.

In fact, all alternative fuel discourses suffered from the declining oil substitution discourse in the mid-1980s. The expectation of a continuously low oil price was given as an argument to cease further investment in wheat ethanol production, and also to end the large funds that had gone to methanol at the time. Nevertheless, when the oil substitution discourse ended, the Swedish self-sufficiency discourse, i.e. the propagation of neutrality and the need for emergency solutions, appeared on the agenda. This was visible in the emerging ethanol discourse, which promoted ethanol as a flexible emergency fuel. To what extent the reappearance of this discourse was a strategic product of alternative energy actors, among them the ethanol coalition, is difficult to judge. What also profited the establishment of the ethanol discourse was that it became more successfully embedded in the growing environmental discourse that demanded solutions to local and increasingly global emissions from the transport sector. The abrupt termination of methanol funding that coincided with the recommendation from the Motor Alcohol Committee to focus on E95 in heavy diesel vehicles indicated that ethanol was taking over the alternative fuel scene. The E95 focus did not come as a surprise to the ethanol actors, especially not the SSEU which had been running bus trials on E95 since the early 1980s.

Despite the advice of the Motor Alcohol Committee not to follow up the small scale crop ethanol production plant in Skaraborg with a larger scale production facility, the crop ethanol coalition did not give up. There was public opposition to this recommendation by representatives of the Motor Alcohol Committee, the Centre Party and the Left Party. They argued that the cost of a full tax exemption to support ethanol production was not as high as calculated by the Committee and that the building of a large-scale ethanol plant that the tax exemption would support was necessary to be prepared for a potential emergency situation (Motoralkoholkommittén, 1986a). In addition, several parliamentary bills, from the Centre Party in particular as well as the Left Party and the Liberal Party, were handed to the government in the late 1980s urging an ethanol tax exemption and support for a large scale ethanol production plant. Their arguments referred to several new scientific findings showing that low blend ethanol provided environmental gains and that domestic ethanol production would contribute to increased national security of supply, increased employment and better use of agricultural land. The farmers' organization Svenska Lantmännens Riksförbund was also a strong lobbying actor for a tax exemption and the wood ethanol coalition continued to support the wheat ethanol discourse. The SSEU argued that a large scale ethanol plant could become profitable, but that the uncertainty regarding the future oil price demanded a government tax exemption. Despite these lobbying activities, the government decided not to grant a tax exemption for continued ethanol production(Näringsutskottet, 1988: 116-117).

Eventually, the overproduction of food crops in the agricultural sector in Sweden and the rest of Europe led to international criticism of the protectionist agricultural policies of Europe (Koneèný, 2004). As a result, farmers' livelihoods and thus a related farmer livelihood discourse were at the centre of attention and the Swedish government published a memorandum (Engström & Hellström, 1990) on a 'New direction in foodstuff policy' in 1990. In this memorandum, solutions were presented for the Swedish agricultural sector to enable its survival once subsidies for domestic food production were reduced. It was argued that the new agricultural policy should be connected to general goals such as environmental issues and national security of supply, which were in line with the contemporary environmental and self-sufficiency discourses. With the growing farmer livelihood discourse, the crop ethanol coalition had additional arguments for promoting ethanol in addition to the linkages made with the environmental and self-sufficiency discourses.

The ethanol discourse was well integrated into the general environmental discourse. This was seen in the implementation of a CO_2 tax in 1990 on fossil fuels. Bio-based fuels such as ethanol were exempted. According to Engström and Hellström (1990), the CO_2 tax was a result of growing interest in climate change in the late 1980s.

As a consequence of the increased CO_2 reduction focus, the government decided to re-evaluate the conclusions of the Motor Alcohol Committee on ethanol as a potential emergency fuel. An Ethanol Working Group was set up to carry out the ethanol evaluation. One of the main questions of the working group was the extent to which the government would support the setting up of a large scale ethanol production plant. This became a highly contentious issue. The Energy Authority (Statens Energiverk), the Agricultural University (Lantbruksuniversitetet) and the large state-owned energy company Vattenfall were some of the actors that were negative about government support. They argued that ethanol production would enter the market on its own once it was sufficiently competitive. The agricultural organizations (Lantbruksstyrelesen and Lantbrukarnas riksförbund) were some of the actors arguing for government support for the construction of a large scale ethanol plant. However, they did not see production support as necessary. Their position was in line with the political intention to cut subsidies on food and for the agricultural industry (Fallde et al., 2007). By these means the ethanol coalition actors kept their alliance with the farmer livelihood discourse, outlined above, and linked up with the more recent government ambition to make the agricultural sector more competitive. According to Fallde et al. (2007), a third position was taken by bioenergy proponents (Svenska Bioenergiföreningen) who agreed with the farmer lobby that there was a need for government support for ethanol, but believed that it would be cheaper to invest in a wood ethanol production plant at the sulphate factories instead of a crop ethanol plant. The conclusion of the working group was that ethanol production would not be economically sustainable if the government did not provide additional support. In 1991, the government gave financial support for the construction of a large-scale ethanol plant (Fallde et al., 2007). When digging into the history of this government decision it becomes clear that it was a result not only of a strategic ethanol coalition and a growing ethanol discourse, but also of a political compromise – the 1991 three-party agreement. Something else had to give to make the ethanol discourse succeed.

The three-party-agreement was the solution to an incompatible political agenda due to two discourse developments and related political decisions in the past. First, as a result of the Chernobyl accident in 1986, the anti-nuclear discourse gained increased attention. The result was a decision to start decommissioning reactors in 1995, which was early given that a referendum in 1980 had set 2010 as the final date for nuclear energy production. Second, the Bruntland report, published in 1987, fed the development of a global environmental discourse, leading to a parliamentary proposal and decision to set a CO_2 emissions cap according to 1988 emission levels. These two decisions were in conflict with previous government commitments to preserve unexploited rivers and keep electricity prices low for industry. Negotiations between the Social Democrats, the Liberal Party and the Centre Party ended up in a policy decision known as the three-party agreement in 1991. This involved the withdrawal of the decision on a CO_2 cap and of the fast phase-out of nuclear power. In return, the main promoter of the anti-nuclear discourse and the farmer livelihood discourse, the Centre Party, gained subsidies for biomass to energy, ethanol use and crop ethanol production. Moreover, to avoid competition with biomass options, a previous decision to expand the natural gas pipeline to Stockholm was reversed (Carlsson & Molin, 1991; see also Fallde et al., 2007).

The withdrawal of the 1988 carbon cap and early nuclear decommissioning did not mean that all environmental issues vanished. The government memorandum (Carlsson & Molin, 1991) stressed the need to reduce CO_2 emissions, but that this would be more successful as part of an international agreement. The international community had been working on an international agreement to mitigate greenhouse gases since 1989 and an international target was set with the UN Convention on Climate Change in Rio De Janeiro in 1992. For Sweden, this target meant a stabilization of CO_2 emissions at 1990 levels by 2000 (Fallde et al., 2007). According to Brandberg and Sävbark (1994), the fact that the international community had made plans for future international CO_2 emission reduction targets in Kyoto indicated growing concern about CO_2 reductions. This was reflected in an increasingly global environmental discourse in the 1990s, which was also reflected in changing arguments by the ethanol coalition. While previous arguments had been linked to the importance of oil substitution or emergency fuel development as well as improvements in the local environment and farmer livelihoods, the post-1993 arguments had a greater focus on CO_2 reductions.

The ethanol discourse gained increased legitimacy as a result of the three-party agreement. This was shown in a 1991 government bill that argued: 'The use of motor alcohols as fuel has advantages from an environmental as well as a national security point of view. It is urgent to stimulate technology development for alternative fuels and to carry out trials with vehicles in densely populated areas in order to gain experience in handling and using alternative fuels' (Carlsson & Molin, 1991: 63, translation by the author).

In practice, the three-party agreement resulted in particularly large funding for a Biofuel Programme from 1992 to 1997, subsidies for a conventional ethanol plant and a general tax exemption for pure and high blend (E85) ethanol fuels in 1993 (Riksdagen, 1991; Bucksch & Egebäck, 1999). The Biofuel Programme had an initial focus on ethanol development, but biogas was added to the programme in 1993. This was due to the growing promise of high environmental gains from the use of biogas (KFB, 1994). This however, does not seem to have bothered ethanol proponents that much. The ethanol coalition teamed up with biogas and biogas to energy proponents to oppose further natural gas expansion. The fear was that once the natural gas network had been spread over the country, biomass options would no longer be able to compete. The reason for this positioning was that the arguments for biogas were in line with farmer interests, such as regional development and the use of farm-based feedstock such as manure and even delivering by-products to farmers such as bio-fertilizer (Mared, 1990; Bengtsson, 1991). In this way, the ethanol and biogas coalitions shared some general features of their discourses.

Farmers did not take up the government subsidies to build the grain ethanol plant. The farmers would not risk undertaking such a venture without the guarantee of an ethanol market – a guarantee which oil companies were not willing to offer (Sandén & Jonasson, 2005). The resistance of farmers to risk connected to new ventures could be traced back to the fact that they had long been part of a protectionist agricultural policy. Another, potentially complementary explanation was the resistance to ethanol in the petrochemical and automobile industries.

That the oil industry was negative about an ethanol blend in fossil fuels was already clear in the mid-1980s (Motoralkoholkommittén, 1986b; Miljö och Energidepartementet, 1989: 364). This resistance to alcohol fuels was also found among automobile producers' argument that 'petroleum oil should be reserved for the transport sector' (Mellde, 1988: 3; Miljö och Energidepartementet, 1989, translation by the author). The antagonism towards alternative fuels remained among oil and parts of the automobile industry throughout the larger part of the 1990s (Brandberg & Sävbark, 1994; Kristenson, 1997b). The lack of support from oil companies became a barrier to further ethanol development, but the ethanol coalition did not give up. The SSEU had been lobbying for the set up of a cellulose ethanol plant since the 1980s. However, due to scientists' arguments that the technology was not sufficiently mature, the plant was not built (Sandén & Jonasson, 2005; Östman, 1998). However, it was generally acknowledged that cellulose ethanol was a technology that had greater potential to reduce CO_2 emissions compared to crop ethanol (Fallde et al., 2007). This motivated the set up of an expensive Ethanol Development Programme supporting cellulose ethanol R&D from 1994 until 1997 (Östman, 1998).

While the farmer-driven crop ethanol coalition mainly lobbied for crop ethanol production, the cellulose ethanol coalition mainly lobbied for the creation of an ethanol vehicle market. This was part of a strategy to create more support for the development of more advanced cellulose ethanol in the future. The efforts of the SSEU were visible in the successful lobbying for funds for both bus and FFV trials during the 1980s and 1990s, and by increased reference to ethanol vehicles as a means to reduce both local and global emissions (see above on ethanol niches). According to Sandén and Jonasson (2005), the decision by the SSEU to push FFV introduction in the 1990s was also a strategic move motivated by a threat to the future expansion and survival of the ethanol bus niche. The threat was the sudden limitation of financial means for bus companies to co-finance additional ethanol trials due to cuts in budgets and the privatization of public bus companies (Sandén & Jonasson, 2005). These cuts occurred generally in the public sector at this time and can be related to a liberalization of Swedish politics starting in the 1980s and accelerating in the early 1990s (Munkhammar, 2007).

While the development of the ethanol discourse appears successful, additional threats appeared in the mid-1990s. When Sweden decided to join the EU in 1995, the institutionalized energy and CO_2 tax exemption for pure and high blend ethanol use in Sweden did not fit with EU rules that restricted tax exemptions to pilot projects (Persson & Åsbrink, 1997). However, the Swedish government did not give way on the EU regulations, but stated that:

> […] the pilot project law should be practiced in a way that prevents any change in the way motor alcohols and vegetable fuels were taxed before entry into the European Union (Carlsson & Nygren, 1994:58; see also: Persson & Åsbrink, 1997, translation by the author)

The Swedish biofuel tax regulations were part of the negotiations connected to Sweden's EU membership. The European Commission stated that no general exceptions to EU tax laws were possible, but that the current volume of biofuels used in the transport sector could fall within the EU tax exemption for pilot projects. Based on this agreement, the government suggested that the current biofuel tax exemptions on the CO_2 and energy taxes would be continued (Carlsson & Nygren, 1994). However, EU membership meant temporarily higher prices for both domestic and imported ethanol, linked to changes in taxes and tolls (Larsson, 1997; Kristenson, 1997b). According to Persson and Åsbrink (1997), EU membership implied no restrictions on ethanol tax exemptions. After additional negotiations, the EU accepted a prolongation of the ethanol tax exemption for five years post 1996 (Kristenson, 1997b). Swedish discontent with the EU pilot exemptions was not only shown by the way in which the government tried to avoid them, but also in strong Swedish support for a planned EU tax reform to a more liberal system in which each member state is allowed to set its own tax levels (Persson & Åsbrink, 1997: 173-174).

Another threat to ethanol expansion was the bioenergy coalition, which opened up a renewed debate on biomass use as the most efficient method of CO_2 reduction. With increased attention on climate change, scientists increasingly argued that CO_2 reduction was more cost-efficient using biomass in the energy and heat sector compared to the use of biofuels in the transport sector (e.g. Gustavsson & Svenningsson, 1996; Gustavsson, Börjesson, Johansson, & Svenningsson, 1995; Fallde et al., 2007). That the conversion of crops to ethanol was rather inefficient had already been pointed out, but previous arguments over security of supply and the maintenance of farmers' livelihoods had overruled the efficiency argument. These arguments were still being made, but gained additional force by means of a new argument introduced to legitimize continued biofuel implementation in the 1990s. The idea of sector responsibility implied that environmental policy goals should be reached in all sectors, including the transport sector and the energy and heat sectors (Fallde et al., 2007). As formulated in the government memorandum 'A good living environment' in 1991: 'emissions of all climate affecting gases should be limited within all societal sectors' (Fallde et al., 2007: 30). Similarly, one of the main arguments used by the 1993 Climate bill was that the transport sector was one of the only sectors to expect an increase in greenhouse gas emissions. Consequently, intervention in the transport sector was of particular importance (Brandberg & Sävbark, 1994). In the same line of reasoning, the 1994 Traffic and Climate Committee, recommended that the government achieve cost-efficiency in CO_2 reduction by dividing the costs of all CO_2 reduction measures equally over all the sectors as far as possible. The Committee on international cooperation recommended avoiding CO_2 reduction investments that would harm international competition, but also stressed the advantage of leading the development of environmentally friendly technologies in the transport sector (Fallde et al., 2007). This was in line with the motives behind the Ethanol Development Programme, an R&D programme which began in 1994, and the ethanol discourse set out by SSEU to investigate the potential to scale-up ethanol activities to a cellulose ethanol plant (Brandberg & Sävbark, 1994; Östman, 1998). Hence, it is possible to conclude that the linkage to the environmental discourse was still of great importance to the ethanol coalition. However, according to Östman (1998), the scientific feasibility studies once again hampered development by arguing that the advanced cellulose ethanol process was not sufficiently mature. The idea that biomass was a limited resource emerged at the end of this period, but was not yet an issue that hampered ethanol development (Fallde et al., 2007).

Because of the increasing attention on CO_2 reductions in the 1990s, two commissions were set up to research the future of alternative fuels. First, the Communications Committee, which was made up of the Director-General of the Swedish EPA and members of all seven political parties in parliament, was set up in 1994 to research and suggest solutions for the transport sector with assistance from 30 experts (Kommunikationskommittén, 1997). Second, the Alternative Fuel Committee was set up in 1995, appointing different scientific experts such as engineers and agronomists to research the potential for alternative fuels to reduce CO_2 and other harmful emissions in an efficient manner (Alternativbränsleutredningen, 1996). The Communications Committee (Kommunikationskommittén, 1997) produced three scenarios for the introduction of 10-15% alternative fuels by 2010. The general route suggested exemptions from the CO_2 tax and the energy tax for renewable fuels. Another central strategy suggested was to introduce low blend ethanol (E5) in gasoline in 2002 at the latest and to guarantee support for domestic ethanol production plants. The focus on ethanol in the advice by the Commission was related to the idea that ethanol was a realistic alternative to fossil fuels, while other biofuels were considered niche-fuels only. In line with the Communications Committee, the Alternative Fuel Commission (Alternativbränsleutredningen, 1996) also insisted on the need to give energy and CO_2 tax exemptions to biofuels as well as the need to implement small percentage mixes of ethanol and Rapeseed Methyl Esters (RME) in gasoline and diesel. The advice outlined in the two reports was in line with the lobbying activities of the ethanol coalition and indicated that the ethanol discourse was growing. Nevertheless, alongside the positive conclusions on ethanol, the Alternative Fuel Committee (1996) concluded that biogas was the fuel with the most environmental benefits. Hence, biogas gained an environmental class A label. This meant that the Committee classified all other biofuels, including ethanol and fossil-based fuels like natural gas and LPG, which received an environmental class B label, as less environmentally friendly than biogas. Conventional gasoline and diesel fuels gained a class C label.

Biogas was much less developed and institutionalized than ethanol, but the environmental recognition given to biogas made it a potential competitor to the leading ethanol discourse. Nevertheless, this was not the main problem for the ethanol actors. A more serious issue was the public consultation requested by the Communications Committee (Kommunikationskommittén, 1997: appendix), which expressed general discontent with the policy focus on ethanol. Many actors, particularly farmers' organizations which had been key supporters of ethanol development, argued for a broader development agenda for alternative fuels. This was partly due to their interest in other alternative fuel options such as RME and biogas.

Despite some negative remarks with regard to the policy support given to ethanol from bioenergy proponents or actors supporting other biofuel solutions, the ethanol discourse remained strong. Both the policy at the time as well as the reports from the Communications Committee and the Alternative Fuel Commission indicate a generally shared idea that biofuels, and especially ethanol, were a suitable means for meeting the growing need for CO_2 reductions in the transport sector. This can partly be explained by the contemporary ethanol coalition, which pushed the ethanol option forward driven by the motive to safeguard farmer's interests.

The Centre Party was one of the primary lobbying actors supporting farmers and environmentally benign technologies such as ethanol. The Centre Party played a key role in bringing the grain ethanol plant back on the agenda after the failure to take up funds in 1991. One example was a policy proposition delivered to parliament by the Centre Party in October 1996, arguing for a general tax exemption for ethanol:

> An increased use of grain ethanol would result in great environmental gains. In addition, many job opportunities would be created in the country, dependence on imports of fossil fuels would decline while the demand from the market, in the shape of bus companies, transport companies and private persons, can be supplied. (Starrin, 1996, translation by the author)

The policy proposition referred to the expanding environmental discourse and the self-sufficiency discourse, which was gaining renewed attention related to the need for less dependence on unreliable oil producing countries. This was a result of the invasion of Kuwait by Iraq, the resulting Gulf War of 1990-1991 and the military actions thereafter. According to Brandberg and Sävbark (1994), the Gulf war increased attention on self-sufficiency in fuels due to the high costs that security of supply implied. In this case the security of supply referred to the military costs of maintaining or creating peace in areas with large oil resources (ibid.). In addition to the environmental and self-sufficiency discourses, the policy proposition referred to the creation of job opportunities that an ethanol industry would bring. This refers to a translation of the farmer livelihood discourse into a broader regional development discourse.

Although this proposition was rejected, support for ethanol spread throughout parliament. One example was a proposition by the Christian Democrats in 1998. Like the Centre Party, it argued that domestic ethanol production would reduce CO_2 emissions and dependence on foreign countries, and stimulate employment. However, it also pointed out that ethanol would create a competitive position for Swedish agriculture. Moreover, the Christian Democratic Party referred to the report of the Communications Committee to gain extra power behind their words and argued the need to support alcohol mixes in gasoline from 2002, for a total tax exemption and for support for the production of ethanol (Gylling, 1998). The Left Party was also positive about support for alternative fuels, both in the form of tax exemptions and financial support to construct a crop ethanol production plant. The argument of the Left Party, however, was mainly CO_2 based and it did not have a clear preference for one fuel (Persson, 1997).

While these propositions were rejected, they indicated a broadening of support for domestic ethanol production in parliament, successful lobbying by the ethanol coalition and linkage of the ethanol discourse with regional development, self-sufficiency and the global environmental discourse. Support for the ethanol coalition was further exemplified by the increasing demand for ethanol that Kristenson (1997b) observed in the late 1990s. One example of the growing demand was the request for an extended tax exemption in time and volume by the biggest ethanol producer and distributor in Sweden - SEKAB. According to SEKAB, this extension was necessary in order to meet the increasing demand for the Stockholm bus fleet, but also the new market order of 3000 FFVs at the time (Miljörapporten, 1999b). According to Kristenssen (1997b), the supply of sulphite ethanol from Örnsköldsvik and southern European wine ethanol were not sufficient for the expanding ethanol market in Sweden. Moreover, the price of wine ethanol, which made up the majority of the ethanol used, was high and dependent on agricultural politics and related agricultural and ethanol tax exemptions from the EU (ibid.). This is likely to have increased uncertainty over ethanol supply and the demand for an extended tax exemption for ethanol production.

In accordance with the advice of the Alternative Fuel Commission, the Communications Committee and the ethanol coalition, the budget bill for 1998 (Persson & Åsbrink, 1997) outlined the need to increase support for the development of an ethanol market in order to stimulate domestic ethanol production. The EU had announced a tax reform that would change the current temporary pilot tax exemptions to a more liberal system where every member state was allowed to set their own tax levels. However, the government could not wait for this reform and decided to prolong the current CO_2 tax exemptions for all biofuels and the exemption from energy tax for pure ethanol use. Finally, the government decided on an additional tax exemption for the use of low blend ethanol or ETBE in gasoline. According to the government, the tax exemptions would be financed by increased fuel taxes (Persson & Åsbrink, 1997: 173-174).

While a competitive and therefore cost-efficient energy market was the first priority in the energy policy of the early 1990s, the 1997 Energy Bill (Persson & Sundström, 1997) was the first to argue that this aim should not be reached at the cost of human health, the environment or the climate. Nor should it hinder the transition to an ecologically sustainable society. To create a transport sector that was both cost-efficient and ecologically sustainable, it was decided to give extraordinary funds to support an additional seven years of the Ethanol Programme based on Woody Raw Materials. Cellulose ethanol technology was the most promising at the time. In this way, the government expected to achieve lower ethanol production costs earlier, and thus be able to implement a more sustainable ethanol technology faster in order to tackle emissions in the transport sector (Persson & Sundström, 1997: 52, 78; see also Fallde et al., 2007: 33). In addition, the Government Energy Bill declared that the construction of the cellulose based ethanol plant would be funded on the condition that it managed to reach low production costs and meet environmental forestry goals (Persson & Sundström, 1997). Parliament agreed the government propositions in 1997 (Persson & Uusman, 1998).

Linkage with the general environmental discourse was a strategy that once again was visible in the ethanol coalition promoting both crop-based and cellulose ethanol. Many developments indicated that the environmental discourse, CO_2 reduction in particular, had gained strength in the late 1990s. One example outlined by the IPCC (2004) was that the EU, and thus also Sweden, was the first to sign the Kyoto Protocol in 1996 (ibid.). Another sign of this environmental trend was visible in the inaugural speech by the Social Democrat Prime Minister, Persson, in September 1996 and the politics that would follow during his administration. Persson expressed his intention to make Sweden a leader in ecologically sustainable development (Riksdagens Revisorer, 1999). The intention to make Sweden a leading environmental country was promoted throughout Persson's time as prime minister (1996-2006). His ambition was often referred to as building a 'green folkhem'. Literally, folkhem means 'home for the people', which is a Swedish metaphor that refers to the building of the welfare state by the Social Democrats in the 20th century. Hence, by connecting green to the concept folkhem, a strong metaphor was put in place which made the mission of saving the environment a societal project (Wikipedia, 2010). This is exemplified in a quote from a Swedish Social Democrat in 2004:

> Just like when we built the 'folkhem' it is about taking responsibility. At that time maybe more a consideration of family and class. Now in solidarity with and responsibility for coming generations. But also in solidarity with other people on our Earth. (Mona Sahlin quoted in Wikipedia, 2010, translation by the author)

In sum, the ethanol coalitions had to work hard to develop and take over a strong methanol discourse during this period. Opportunities for the ethanol coalitions were created by the emergence of the self-sufficiency discourse promoting the need for an emergency fuel and later independence from politically unstable countries, the farmers' livelihood or regional development discourse and the growth of the environmental discourse from local concerns to include more global concerns. Regarding discourse change, interest was lost in crop-based ethanol production after 1991, but ethanol use in vehicles gained support and cellulose ethanol production gained even more so due to its close association with the growing environmental discourse focused on CO_2 reductions. The ability of coalition actors to connect with the major discourses has proved successful for the development of the ethanol discourse, but the compromises in high level political negotiations in 1979 and 1991 also provided incentives for the support of ethanol as a transport fuel.

Another development in this period was the appearance of the word 'biofuels', which was used instead of 'alternative fuels' from 1990 in the literature studied. This indicates a new feature in the ethanol discourse – the environmental qualities of ethanol alongside the potential for ethanol to act as an alternative to fossil fuels. This reflects the growing strength of the environmental discourse in this period and the need to distance from less sustainable fossil fuels. The growing strength of the ethanol discourse and the environmental discourse is also shown in the implementation of a CO_2 tax on motor fuels in 1990, which punishes fossil fuels and rewards biofuels.

7.2.4. Alcohol/ethanol discourse analysis, 1980-1997

General policy developments affecting ethanol initiatives					
Policy	**Level**	**Year**	**Type**	**Size SEK**	**Explanation**
1979 energy policy compromise	Government	1979	Energy policy	?	Political party conflict with regard to nuclear energy results in compromise leading to increased support for bioenergy/biofuel.
SDAB	Government, industry	1981-	R&D, communication	?	SMAB becomes the State's Propellant Technology Company (SDAB). Alternative fuel focus benefitting ethanol.
Energy Research Programme	Government	1980s	R&D funding		Ethanol R&D funding started in 1980/81, but remained very limited throughout the 1980s in comparison to other biofuel alternatives.
Tax exemption all alcohols	Government	1981-	regulation	?	1981: reduced fuel tax with 50% on ethanol
SSEU	Municipality	1983-	R&D, communication	?	SSEU founded 1983 to explore (cellulose) ethanol production and use.
CO_2 tax	Government	1990-	regulation	?	CO_2 tax on fossil fuels. All biofuels exempted.
General tax exemption for ethanol	Government	1991-95	Regulation	?	Pure ethanol use gains general tax exemption. EU membership in 1995 puts an end to this regulation.
TFB/KFB Biofuel programme	Government, industry, municipalities etc.	1992-97	R&D and demo	Total 315 million, of which government 120 million	R&D and demonstration of conventional ethanol (later biogas included) as a result of three party agreement. For funding, 50% co-financing necessary.
Rio de Janeiro declaration	UN	1994	Agreement	?	Non-binding agreement to stabilize CO_2 emissions in 2000 to the level of 1990.
EU pilot tax exemptions	EU	1995-	regulation	?	1995 onwards, tax exemptions followed the EU pilot exemption as a result of EU membership.
'Green folkhem'	Government	1996-2005	Vision	?	Prime minister states that he intends to make Sweden leading in environmental development.
Kyoto agreement	UN	1997	Agreement	?	Non-binding agreement for CO_2 reduction in 2012 with 1990 as reference value.
Alcohol fuel standard	Government	1997	regulation	?	Standard developed for alcohol use in diesel engines.
Ethanol initiatives					
Policy	**Governance level**	**Year**	**Type**	**Size SEK**	**Explanation**
Sulphate/wood ethanol production	Government	Ca 1940-	production	?	Since 1940s sulphate ethanol production to support chemical industry. From the 1980s, part of SSEU ´s interest in vehicle fuels.
SCANIA bus trials	Industry	1973-about 85	Field trial	?	Saab-SCANIA runs ethanol bus trials in Brazil and Sweden
wheat ethanol plant	Government, industry	1981-87	production	Government 30.1 million	1983-87: Västergötlands Lantmäns etanolfabrik, wheat ethanol plant.
SDAB: 2 vehicles on E7	Government	1980-82	Field trial	?	SDAB runs ethanol vehicle trial with 2 cars on 7% ethanol mix in gasoline.
E95 buses in Örnsköldsvik / Västernorrland	Municipality	1985-2000	Field trial	?	2 buses on E95 in Örnsköldsvik, set up by SSEU, local bus company, Scania ethanol engines, and SEKAB.
	Government, Municipality	1993-	Field trial	Total 8.24 million mainly by municipality and (KFB) government	1993-Project Västernorrland, follow-up on Örnsköldsvik bus trial. Additionally 4 buses in 1993 and 2 buses in 1996. Total 8 buses running in Västernorrland.
2 buses in Gothenburg/ Stockholm		1986-	Field trial	?	2 buses on ethanol in Gothenburg. Later transferred to Stockholm public transport company (SL).
32 buses in Stockholm	Government, municipality	1990-92	Field trial	SL 20.6 million, Government 27,6 million	SSEU initiates Stockholm trial, adding 30 buses to the 2 running.
	Government, municipality	1992-	Field trial	5.1 million by Government and SL.	2nd phase Stockholm trial with 32 buses 1992-93. They continue running after 1993.

Svenol ethanol trucks	Government, municipality, industry	1991-94	R&D	?	Svenol 1st phase: benchmark for 7 l. diesel engine on ethanol.
	Government, Industry (Volvo)	1995-97	Field trial	Main funds (KFB) government	Svenol 2nd phase: 4 heavy vehicles runs in 1995 and additionally 3 in 1997.
R&D projects	Government	1992-95	R&D, communication	(KFB) government	A variety of emission and engine technology related experiments run by Lund University, Chalmers technical University, Beryl Nobel, AVL Gezellschaft für Verbrennungskraftmaschinen and reports by consultants.
SSEU ethanol in diesel		1992-97	R&D, field trial	?	1992- ethanol mix in diesel, initially lab tests. From 1995-1997 4-21 (heavy) vehicle trial.
Skaraborg bus trial	Government, municipality	1993-96	Field trial	Total budget 9.9 million of which 3.8 million (KFB) government	15 ethanol buses in Skaraborg.
Ethanol development programme	Government	1993-97	R&D	Government 45 million	Several cellulose ethanol R&D projects related to hydrolysis, fermentation and lignin.
SSEU FFVs	Government	1994-	Field trial	(KFB) government	1994 3 Ford FFVs Örnsköldsvik, 1995 50 additional FFVs, 1996 PR tour lead to total of 300 FFVs and 30 E85 pumps in 1997 spread all over Sweden.
OK/Q8 E10	Industry	1997-2000	Field trial	?	10% ethanol mix in gasoline introduced by OK/Q8.

Table 22: Ethanol-related policy development, 1981-1997

Biofuel	Discourse	Mobilization/ impact of wider discourses, events and policies.	Discourse coalition	Target audience	Key activities, strategies	Resulting space/policy creation or disruption
Conventional and advanced ethanol production, and use in E95 diesel buses, trucks and in E85 FFV cars.	Early 1980s: second best alcohol fuel to aid oil substitution and farmer livelihoods. From mid 1980s: the most suitable emergency fuel due to high flexibility, particularly beneficial for the environment on both a short and long term. In the 1990s: best fuel alternative to reach better environment and regional development	Initial embedding in the alcohol discourse, oil substitution and farmer livelihood discourses. In the mid 1980s the oil substitution discourse was replaced by a self sufficiency discourse. In the 1990s embedding in global environmental and farmer livelihood/regional development discourse dominated. Events such as the second oil crisis, nuclear referendum and three party agreement aided ethanol discourse development.	Farmer organizations, the Centre party, farmer owned oil distribution company OK and chemical ethanol producer SEKAB, local authorities and researchers represented in SSEU.	Lobbying was oriented towards the government and later local authorities, firms when it came to FFVs.	Lobbying by means of media, scientific reports and participation in political debates. Increased public campaigning in FFV case. Main strategies were: first, reference to ethanol as an alcohol to gain acceptance in an alternative fuel arena dominated by methanol. Second, reference to conventional ethanol as a bridge to more advanced cellulose ethanol to gain support for both options.	Fuel tax exemption in 1981 that increased in the 1990s. Subsidies for temporal conventional ethanol plant in 1980 and cellulose ethanol R&D and fleet development which increased in the 1990s with the Biofuel programme.

The early ethanol coalition presented conventional crop ethanol as a second-best alcohol fuel, which due to its similar properties to methanol could assist in oil substitution. Through these means it became accepted by the methanol dominated alcohol discourse and more general oil substitution discourse. Once the oil price normalized in the mid-1980s, ethanol became seen as a more suitable emergency fuel than methanol and gained embedding in the self-sufficiency discourse that replaced the oil substitution discourse. This was facilitated by an ethanol discourse that stressed the increased flexibility of ethanol compared to methanol and its relatively low cost. Additional arguments for choosing ethanol over methanol were the environmental benefits of using a biomass as feedstock from both a short- and a long-term perspective, which referred to the ability to step over to a cheaper and more advanced cellulose ethanol technology in the future, and the ability to support the agricultural sector.

Throughout this period, commissioned texts and arguments from coalition actors indicate additional discourse shifts, from referring to ethanol as an emergency fuel to a means for oil substitution, from a means for local to increasingly global emission reduction, and from aiding the agricultural sector alone to regional development in general. While the competing methanol discourse served as a barrier at an initial stage, this barrier was overcome once ethanol became successfully embedded in the general self-sufficiency discourse, the environmental discourse that shifted focus from local to global emission reduction and the farmer livelihood discourse that was replaced with a regional development discourse. In addition, several events aided ethanol discourse development. Examples of this were: the second oil crisis, which led to increased urgency and widened the focus on methanol to other possible biofuel options; the nuclear referendum, which resulted in more attention on biomass-based solutions; and a policy compromise – the three-party agreement – which led to support for a programme on biofuels alone.

The discourse referred to both conventional crop ethanol and more advanced cellulose ethanol in the future, represented by two interest groups in the coalition. First, crop ethanol promoters, e.g. farmers' organizations, the Centre party and the oil distribution cooperative OK. Second, cellulose ethanol promoters, involving the chemical sulphate ethanol producer, SEKAB, farmers' organizations, local authorities and researchers, together represented in the SSEU. Together, these two groups lobbied for an expanding ethanol vehicle market to meet the market for both fuels. These activities were mainly undertaken in the media, scientific reports and political debates. Public campaigning was also a measure to gain support for FFVs. An example of a successful strategy used was reference to ethanol as an alcohol to gain acceptance in a society in which methanol dominated the alternative fuel discourse. Another example was the reference to conventional ethanol as a bridge to more advanced cellulose ethanol as a means to gain support for both alternatives. In addition to their wide lobbying strategies, the great variety of actors, the degree of collaboration and their ability to influence the policy agenda contributed to great discourse expansion after a relatively slow start.

This discourse expansion resulted in substantial ethanol support measures. These measures increased during the 1990s, involving more extensive tax exemptions for bus and later FFV fleets and cellulose ethanol R&D funds as shown in Table 22. In addition, the standardization of ethanol fuel properties and engine technology, and the institutionalization of tax exemptions, indicate the increased stability of the discourse.

7.3. BIOGAS DEVELOPMENT AIDED BY NATURAL GAS, 1986-1997

This section describes the emergence of biogas production and use in the period 1980-1997, which was both aided and threatened by the natural gas actors. First, I present the development of the biogas niche followed by an SNM analysis. Second, I describe the political processes leading up to biogas policy followed by a discourse analysis.

7.3.1. Biogas niche development, 1986-1997

The development of biogas vehicles profited from the introduction of natural gas vehicles, since they use the same technology and standards. Hence, before describing the biogas development trajectory I give a brief introduction to the initial natural gas vehicle trials.

Natural gas became available in the mid-1980s when a pipeline was built from Denmark to Malmö (Statens energiverk, 1987b). The location of this pipeline is likely to have facilitated the first experiment with natural gas vehicles, which took place in Malmö with Malmö Energy and Malmö Transit Authority . Buses, previously used in an LPG[61] trial by the same authorities, were refitted to enable the use of natural gas. Malmö Energy distributed the fuel and installed a gas refuelling system with an Italian Nuevo Pignone compressor at the bus garage. A trial involving three natural gas buses ran in the city of Malmö in 1986 with the aim of making the use of natural gas bus technology credible. The government did not help finance the trial (Ekelund, 1993).

At the same time, the Nordic Gas Bus Project (Nordiska GasBuss Projektet) emerged from a seminar on the problem of emission reduction from city busses arranged by the Nordic Board of Ministries (Nordiska Ministerrådet) in Esbjerg, Denmark, in December 1986. Many of the parties at the seminar saw natural gas as a solution to the emissions problem, and in 1988 transport officials in Helsinki, Copenhagen, Malmö, Oslo and Stockholm formed the Nordic Gas Bus Project to investigate the potential for emissions reductions from gas engines. The main sponsor of the project was the Nordic Industrial Fund (Nordisk Industrifond). In addition, 30 firms and organizations contributed SEK 10 million for the development of low emission natural gas engines. Assignments were given, first, to the engine laboratory Ricardo in England to convert an 11 litre Scania diesel engine and ,second, to the Southwest Research Institute to convert a 9.6 litre Volvo diesel engine in cooperation with Volvo. A series of emission tests were carried out with the engines, which delivered low emission results. In 1990, when the first phase of the project ended, the results were presented at the conference of the International Association for Natural Gas Vehicles in Buenos Aires. The project gained a lot of attention and received prizes. In its second phase, the project leaders had planned to set up small-scale trials with low emission natural gas and biogas buses in 1991 and to introduce large scale trials in 1993-94. However, when the first phase of the Gas Bus Project ended in December 1990, plans changed. Volvo and Scania decided to continue the project alone based on their judgment that there was sufficient commercial potential (Ekelund et al., 1993). Both the environmental promise of gas vehicles emerging from the first

[61] Liquefied Petrol Gas (LPG), a by-product of the oil refineries, was first tried in Sweden in the 1970s. Although fossil based, LPG is a cleaner fuel than regular gasoline or diesel, but it requires a bi-fuel vehicle, that is a vehicle with an extra tank with conventional fuel. The use of LPG was made attractive due to a 50% tax reduction compared to regular fuels. Taxi companies were the first to introduce LPG. Eventually, LPG in taxis and cars became a market niche. However, the niche peaked in the early 1980s, with a total number of 3000 cars, and declined drastically in the late 1980s. One reason for this radical decline was a plan by the government to increase the LPG tax. While this never happened in the 1980s – in fact, taxes were reduced - the trust in LPG was lost (Statens energiverk, 1987a). Another potential reason for the decline in LPG sales is the sudden availability of natural gas in the mid-1980s.

project phase (Ekelund et al., 1993; Ahlbäck, 2003) and the natural gas supply (Ahlbäck, 2003; Sandén & Jonasson, 2005) were highlighted as contributory factors for the market expansion of gas vehicles. An example of the expanding market was the purchase of 20 natural gas buses in 1991-1992 by Gothenburg City. Despite technical problems and complaints about the limited power of the buses, the City kept the buses running (Ahlbäck, 2003; Ekelund, 1998). Another example was an order for 252 Scania buses from Sydney in the early 1990s. Consequently, the second phase of the Nordic Gas Bus Project changed its aims from supporting trials to eliminating social, industrial and legislative barriers to running heavy vehicles on natural and biogas (Ekelund et al., 1993). The transport officials in the Nordic Gas Bus Project decided to include a transport official from Gothenburg in their team. While the Nordic Board of Ministries contributed the main part of the financing, the different partners, e.g. city transport officials, vehicle manufacturers and energy suppliers, also contributed to the total of SEK 6,27 million for the second phase of the project. Italy and New Zealand had sophisticated standards with regard to natural gas vehicles, there were none in the Nordic countries. Consequently, the second phase of the project introduced a 'Code of Practice' to be able to judge the quality of natural gas vehicles and filling stations and thereby minimize the legal bureaucracy for further implementation. The project also made great progress in the development of an international ISO vehicle tank and fuel storage standard. In addition, the project commissioned a variety of studies covering international experiences with gas vehicles in order to learn to deal with social and industrial barriers. The security of the fuel was considered a particular social barrier; hence, one of these studies showed that the use of natural or biogas vehicles was not less secure than the use of conventional fuels (Ekelund et al., 1993).[62] The Nordic Gas Bus Project ended in 1994 (Ekelund, 1998).

The implementation of natural gas buses in Gothenburg in the early 1990s got Volvo increasingly involved in the gas vehicle development. Volvo developed the gas buses for the Gothenburg trial (Ahlbäck, 2003). The collaboration with the city evolved when the city asked Volvo to constructs 5 gas cars for the 1995 World Athletics Championships in Gothenburg. These were conventional Volvo cars refitted to run on bi-fuel, i.e. cars with one fuel tank for gas and one for gasoline. Due to positive media attention, a taxi company in Malmö ordered 50 bi-fuel cars for delivery in 1996. Eventually, Volvo produced 160-170 first-generation bi-fuel gas cars. Volvo sold some of them in Stockholm, but a greater number abroad. In 1997, Volvo started to produce a new, more advanced version of the V70 bi-fuel car, but senior management disagreed and production was stopped (Sandén & Jonasson, 2005). According to Williander (2006), the decision to stop the production of bi-fuel cars was linked to a change in the engine technology which increased the price of the vehicle to a level that few fleet owners were willing to pay, coupled with the change to a new company CEO who prioritized short-term performance and low cost. Nevertheless, interest in the bi-fuel technology did not vanish (Williander, 2006). Only a few months after the production halt, Volvo decided to include bi-fuel vehicles in large-scale production of the Volvo S80 series based on the argument that Sweden's large oil dependency had to be reduced (Sandén & Jonasson, 2005).

The initial plan of the Nordic Gas Bus project to experiment with natural gas and biogas was not extraordinary because natural gas and biogas are very similar. They both have methane as their main component. In fact, biogas actors developed a biogas standard, which, although not official, matched natural gas vehicles. According to Lothigius (Lothigius, 1997), biogas had to be upgraded to 97% methane to be able to run in natural gas vehicles. According to Kullbjer (Kullbjer, 1995), this was a strategic move that enabled biogas users to

[62] Ekelund et al. (1993) show quite different information on the Nordic Gas Bus Project compared to Ekelund (1998).

take advantage of natural gas developments. Ekelund (Ekelund et al., 1993; Ekelund, 1998) acknowledged that biogas development could be facilitated by natural gas and related infrastructure development. In addition, Ekelund (Ekelund, 1998) argued that the development and introduction of biogas was initially a matter of the limited natural gas supply. Once biogas supply, upgrading technology and use of biogas in gas vehicles were proved viable, the benefit of using renewable and non-CO_2 emitting biogas instead of natural gas would become more obvious. Ekelund (Ekelund, 1998) also argued that in 1997 use of biogas was not being facilitated by the natural gas industry – it was not transmitted in the natural gas pipeline although there was no technical reason not to do so. Furthermore, he argued that authorities were hesitant about accepting and supporting biogas. However, there are many arguments against Ekelund's statements. While the natural gas actors may have been restrictive in distributing biogas in the natural gas pipelines, Held (2008) indicates that the energy company Göteborg Energi transported biogas through the natural gas pipeline in the second half of the 1990s. While some may have been hesitant towards biogas, the great biogas support indicates that the great majority of authorities shared positive biogas expectations. Examples of this were the energy tax exemption that biogas had gained from the government (Bildt & Wibble, 1993) and the decision by the national authorities that biogas field trials were to be supported by the Biofuel Programme from 1993, although the main motive of this programme was to scale-up the ethanol bus trials (KFB, 1994).

The first experiment with biogas buses in Sweden took place in Linköping, a city in the South of Sweden that at the end of the 1980s was facing increasing problems with inner city pollution. To improve inner city air, two options were proposed. First, a so-called duo bus with diesel and electric propulsion and, second, a gas bus. That the city of Linköping was on the route from Gothenburg to Stockholm on which the government and the gas company Swedegas planned to run the natural gas pipeline made gas particularly interesting. In addition, there was a small natural gas source on Östgötaslätten, 30 km from Linköping, which could be exploited until the pipeline was built. The transport office of the cities Linköping and Norrköping (Linköping-Norrköping Trafik AB), LITA, gained financial aid from the TFB/KFB Biofuel programme. They appointed a consultancy firm to carry out a cost-benefit study of the potential to use Östgötaslätten as source for vehicle gas, but it was considered too expensive to exploit. A second alternative appeared – the biogas from the new wastewater plant installed by Tekniska Verken for Linköping municipality. The option seemed suitable and LITA sent out a plea for partners who could contribute to the project. The government agencies NUTEK, TFB/KFB and Naturvårdsverket supplied most of the funds. Additional actors supported the project: private companies (Statoil Lubricants, Scania) and actors related to the local authorities (Tekniska verken, Östgöta Trafiken, Landstinget i Östergötland) as well as the Stockholm public transport company, SL. Scania and SL, however, withdrew almost immediately. SL to focus on ethanol in Stockholm, where a trial with ethanol buses was close to commercialization. The budget of the project was SEK 16.3 million. LITA contributed SEK 8 million, which was mainly own work and expenses. The aim of the trial was to run 70 000 km with each bus in a period of 18 months in order to test vehicle operation, the technology, economy and the potential for up-scaling. A secondary aim was to look at the pros and cons of biogas production. LITA refitted five Scania buses for biogas propulsion. Statoil supplied the project with special lubricants for the engine. The biogas from the wastewater plant Tekniska Verken in Linköping had to be upgraded before it could be used in the buses. To save costs, LITA refuelled the gas buses at the wastewater plant. The five biogas buses started to run in the spring 1992. Initial problems appeared with the engine technology and there was a fire in one of the buses. However, nine months later the drivability was equal to that of a diesel bus.

Compared to diesel buses, LITA considered the buses faster when starting, but less powerful at higher speed. Other results presented by LITA were that the gas buses ran smoother, and produced less noise and fewer emissions. Nevertheless, the emission tests delivered quite uneven results. LITA's expectation was that especially HC and NO_x emissions could be reduced even more. Throughout the project period, LITA communicated project progress and results both nationally and internationally. According to LITA the realization that high quality methane, equal to natural gas quality, could be gained from wastewater installations with an almost non-existent CO_2 contribution, was crucial for support and continued project development (Kullbjer, 1995). Moreover, according to the final report on the LITA project (Kullbjer, 1995), the experiences delivered by LITA inspired the development of up to 13 other biogas projects in Sweden and interest from international partners. This referred to the US Department of Energy (DOE), which started a similar project in Colorado Springs, Washington D.C. and Ramona in California. According to Lothigius (1997), even a project in France was inspired by LITA.

During the LITA project, the municipality of Linköping investigated the possibility of setting up an anaerobic installation for waste with the goal of producing biogas and fertilizer as a by-product. The municipality already owned Tekniska Verken and acquired interests in this project. Together with agricultural organizations such as Scan-Farmek, LRF and Konvex, the municipality set up a new company – Linköping Biogas AB. The feedstock for the anaerobic installation was manure and waste fats. LITA, which had now split into two public transport companies, Östgötatrafiken and Näckrosbuss, wanted to use more biogas and took part in the planning of the project, starting in 1995. To create a biogas market for the plant, a complementary programme was set up in April 1996 called the Inner City Buses of Linköping (Linköpings Innerstadsbussar). The aim of this programme was to set up a permanent biogas filling station, and to convert all inner city buses to biogas and start a trial with biogas cars. KFB's Biofuel Programme gave funds to the complementary programme. The vehicles were delivered in June 1997: 22 buses, of which 11 were Volvo and 11 Neoplan, and 2 Volvo bi-fuel cars of which one served as a taxi and the other at Tekniska Verken. According to Volvo, the bi-fuel car was the cleanest car tested in their laboratories. An additional 21 buses, of which 15 were Neoplan and 6 Volvo, were ordered for the period October 1997-February 1998. The gas filling station was bought from a company in New Zealand. Because of a delay in the construction of the gas filling station, the buses were initially filled up at the old filling installation at Tekniska Verken. In May 1997, the new filling station in Barhäll was ready for use and the new anaerobic installation, also heavily delayed, was installed in Åby. As planned, the installation mainly used butchers' waste and manure, producing a by-product that could serve as a fertilizer in the agricultural sector (Brolin, Carlsson, & Kullbjer, 1997). The evaluation in June 1997 by Brolin et al. (1997) took place too early to judge the development of the installation. It was stated that the delays were due to problems with the materials used. However, they concluded that both the buses and the new anaerobic installation had run satisfactorily thus far (Brolin et al., 1997).

Many Swedish projects got their inspiration from the LITA trial in Linköping. Kullbjer (1995) mentions several activities in 1995. First, Södertälje waste management facility carried out a pre study investigating the possibility of running their vehicles on biogas. Second, Ryaverken in Gothenburg put biogas trucks in operation. Third, an energy plant in Jönköping evaluated the possibility of using landfill gas for vehicle propulsion. Fourth, the municipality of Trollhättan carried out a vehicle project on biogas. Fifth, Södertörn's waste disposal plant investigated the possibility of running 20 of their vehicles on their own landfill gas. Below, I outline the projects with sufficient documentation – the biogas projects in Trollhättan, Gothenburg, Stockholm and Uppsala.

Like Linköping, the city of Trollhättan was also preparing for the natural gas pipeline. The initial plan to expand the gas network to additional cities north of Gothenburg, such as Trollhättan and Uddevalla and Vänersborg, was expected in 1990-1991 under the project label Västgas II. However, the project was postponed by one year and eventually Swedegas terminated the project in 1990. A potential reason for the closure was the recent takeover of Swedegas' shares in Västgas II by Vattenfall and Vattenfall's withdrawal from investments in energy production from natural gas (Moberg, 1991). The loss of the pipeline led Trollhättan municipality to choose biogas based on the expectation that it would contribute to regional development. Eventually, other partners joined the project, such as the national energy company Vattenfall, the local energy company Trollhättan Energi AB and the National Maritime Administration (Sjöfartsverket). Initially, 1990-1993, studies were set up to research the feasibility of a biogas project. This led to a broader focus, as indicated in the name of the project: 'Biogas in Trollhättan for Vehicles in Coordination with Waste Management and Energy Production'. In May 1993, after various requests for funds, the project gained SEK 10.9 million from the KFB. However, the expenses increased during the project and the total fund from KFB was SEK 13.1 million of which SEK 3.9 million was spent on vehicles alone. The total project budget, including the matching funds of the various project partners, was SEK 30.7 million. The aim of the project was to test the possibility of using the biogas produced at the wastewater plant as fuel for local bus and truck fleets. Trollhättan Energi and Vattenfall were responsible for the gas pipeline and the filling stations. Additional partners joined, such as the local wastewater company Tekniska Verken owned by the municipality in Trollhättan, which cleaned and provided the biogas fuel, and the public transport company Älvsborgstrafiken AB, which provided the main bus fleet for the trial. While the project period set out by KFB was 1993-1996 and the first bus trials were scheduled for 1994, actual trials started in 1996. This was partly due to financial problems, the delay in the delivery of vehicles, problems in granting biogas deliveries and weather conditions, which delayed the construction of the biogas pipeline. Of the four buses that started running in 1996, three were Volvos and one an Ontario. In 1997 a delivery of six additional buses was expected. In addition to the buses, two Volvo trucks for waste collection were delivered in early 1997. These were the first trucks to run on biogas, which according to Volvo was the reason for the delay. Finally, there were some personal vehicles of the bi-fuel type. A few of these were Volvo 850s run by Vattenfall and one Saab 900 run by Trollhättan municipality. The emission tests with the buses did not meet the requirements set. However, after the replacement of the old engines with a new generation engine technology in March 1997, the emissions reached the requirements and were acceptable according to KFB. The initial emission test with the biogas trucks was negative, since NO_x emissions exceeded those of a diesel truck. However, Volvo promised improvements. With regard to the anaerobic digesters, there were complaints about the smell. In particular, the public perceived the use of fish waste for gas production as a problem despite improvements in the handling of the waste to avoid smells. Finally, the project resulted in a lot of good will for Trollhättan municipality and contributed to the fact that they received an environmental prize from the King of Sweden for the best work to realize the UN Agenda 21 on sustainable development (Lingsten et al., 1997).[63]

[63] Chapter 28 of Agenda 21 declares it the responsibility of local authorities to construct infrastructure, monitor and execute planning processes, and develop environmental politics and rules at the local level as well as executing national environmental policy. The goal was to set out a 'local agenda 21' for municipalities by 1996 at the latest (Regeringskansliet, 2011). A local Agenda 21 is high on the Swedish agenda, which is indicated among other things by the many municipal and national initiatives, such as the development of national environmental goals, and subsidies such as the LIP and KLIMP funds (SKL, 2010).

The city of Gothenburg, which initially had a natural gas focus due to the accessibility of natural gas and the development of gas vehicles at local Volvo factories, also gained an interest in biogas. An anaerobic digestion installation was set up in 1990 by the Gothenburg Regional Sewage Works (Gryaab) to take care of the excess sludge produced at the local waste management company Ryaverken (Held, Mathiasson, & Nylander, 2008). According to Ahlbäck (2003), the initial reason for the biogas plant was to reduce the high transportation costs and odour of the sewage waste. According to Held et al. (2008), the plant had two digestion chambers that used a mesofile, i.e. low temperature (37ºC.), digestion technology. The construction costs of SEK 88 million were financed privately. The biogas was initially used for electricity and heat production and later fed into the natural gas grid of the city. Before feeding the biogas into the natural gas grid or gas vehicles, it had to be cleaned and upgraded to natural gas quality. In 1992 the Swedish Methane Technology foundation (Svensk Metanteknik) initiated the set up of a small-scale biogas upgrading facility at the Gryaab biogas plant of the Ryaverken (Held et al., 2008). According to Ahlbäck (2003), the upgrading facility was set up to produce sufficient gas to run five of Gryaab's cars on biogas. The gas upgraded was less than one percent of the total biogas produced, sufficient to run 13-15 cars (ibid.). Despite having the capacity, the experiment which started with the inauguration of the first biogas filling station for cars in 1994 did not expand beyond 10 biogas vehicles (Ahlbäck, 2003; Held et al., 2008). While Gryaab had the only biogas vehicle experiment in Gothenburg in this period, Gothenburg politicians decided in 1992 to increase the use of biogas and vehicle use in the region. As a first step, Gryab increased biogas production by recruiting additional waste management facilities that could supply feedstock (Ahlbäck, 2003). The access to extra fatty feedstock increased the production at Gryaab in 1996. As a result, about 60 000 MWh of raw biogas was produced, of which 0.2 % was upgraded for use in Gryaab´s vehicles and the rest was upgraded and distributed into the natural gas grid by the energy company Göteborg Energi AB (Held et al., 2008). According to Ahlbäck (2003), advances in the neighbouring city Trollhättan inspired further initiatives by the municipality of Gothenburg.

In Stockholm there were also wastewater plants producing biogas, some of the gas was used for heat and electricity generation while the rest was treated as waste. The biogas project in Stockholm began as a pilot to evaluate the use of biogas as a fuel at the initiative of Stockholm Vatten AB, the public sector company responsible for fresh water distribution and sewage treatment in the Stockholm municipality. In the first phase of the project, it planned to test a fleet of 20 biogas cars with potential expansion to 50 or more. The project partners ordered the technology from Australia and constructed a biogas cleaning unit and a pump next to the wastewater treatment plant in Bromma (Rahm, Brolin, Rudholm, & Lilja, 1997). The investment made with regard to the biogas treatment plant and related facilities was SEK 7.39 million of which SEK 2.34 million was granted in subsidies.[64] In addition to funds gained from KFB and the Swedish EPA, Stockholm municipality gained EU funds from the ZEUS programme. The municipality of Stockholm coordinated the ZEUS programme together with other European cities and implemented it in 1994. One of the sub-projects of the ZEUS programme was to facilitate the introduction of biogas production and biogas vehicles (Energie Cités, 1999). The Stockholm project partners bought Volvo, VW, and BMW vehicles. After some delay, the gas distribution system was ready in the summer of 1996. By June, Stockholm had introduced the first 61 vehicles. The transfer of the project initiated by Stockholm Vatten AB to the Clean Vehicles in Stockholm project contributed to the fast implementation. Local authorities in Stockholm used the vehicles, such as the Bromma wastewater plant and the local parking company Parkeringsbolaget (Rahm et al., 1997).

[64] Original amounts in € converted using the 1999 exchange rate.

The Clean Vehicles in Stockholm project was set up by the city of Stockholm in 1994 and run by a project group as part of the city's Environment and Health Administration (Miljöbilar i Stockholm, 2004: 2). The initial aim of the Clean Vehicles project was to provide environmentally friendly vehicles for Stockholm municipality (Stockholms stad, 2009). As a result of a study by the Clean Vehicles in Stockholm project in 1996, the municipality decided that environmental vehicles should substitute for 300 conventional cars in the city. Of these 300, about 180 were set out to be biogas vehicles by the end of 1997. Vehicle procurement was fast due to the high motivation to meet the goals set out by the project. The growth of the biogas car project in Stockholm made a totally different infrastructure necessary. As before Clean Vehicles in Stockholm applied for a grant from the EU ZEUS program. The amount of funds gained is not clear, but it was assigned for the set up of several biogas pumps and a biogas distribution system based on high-pressure storage. Oil distribution companies such as OK, Statoil and Shell were interested in cooperating. To meet the demand, the wastewater treatment plant in Bromma started expanding its capacities in the summer of 1997.

The production of quality gas was problematic during the initial stages of the project. The bi-fuel vehicles worked very well, except for a VW Golf that became less efficient after conversion to a hybrid from pure gasoline. People were generally positive about the gas vehicles and appreciated reduced smells and the quiet operation. Negative comments concerned the limited range of the gas tank, which was 150-200 km, the limited availability of biogas filling stations and the design of the gas filling gear, which some considered inconvenient. However, the filling itself was considered very fast, only 2-3 minutes. Other problems were the high price of the vehicles, which was SEK 15 000–20 000 more than a conventional car. Moreover, there were only large vehicles available, which made them less environmentally friendly. However, the growing demand was expected to lead to increased variation in vehicles and reduced prices. The emissions of the gas vehicles were lower than those of gasoline vehicles. In particular, nitrogen oxides and carbon monoxide emissions from gas vehicles were very low (Rahm et al., 1997).

The project in Uppsala was similar to that in Linköping because the waste-based vehicle biogas had fertilizer as a by-product. The idea emerged when Uppsala municipality, in cooperation with the Swedish University of Agricultural Sciences (SLU), the Swedish Institute of Agricultural and Environmental Engineering (JTI) and the Swedish Environmental Research Institute (IVL), looked for an environmentally friendly and economically efficient way to deal with the recycling of local waste streams. They saw a large scale anaerobic digestion installation that used different waste streams from slaughterhouses, the medical industry, retail, restaurants etc., while producing biogas and fertilizers as the best option. While waiting on the realization of the gasification installation, the municipality of Uppsala and the municipally owned Uppsala Bus Company (Aktiebolaget Uppsala bus) planned a preparatory phase in 1995 with a threefold aim. The first aim was to set up a biogas distribution system by means of a gas cleaning and gas filling station in connection with an old wastewater treatment plant. The second aim was to demonstrate and expand the biogas vehicle park with 20 buses, one truck and two biogas cars. Third, the project aimed to enable the development of a future biogas market in connection with the planned large-scale anaerobic digestion installation. The KFB Biofuel Programme granted the project funding. In the autumn of 1996, a pump installation in the bus garage and a gas cleaning installation connected to the gas production at the wastewater plant were ready for use. In June 1997, six gas buses from Neoplan, six bi-fuel gas cars from Volvo and VW and one garbage truck constructed in New Zeeland were put into operation. The bi-fuel cars ran for various municipal offices. During 1997, another eight gas buses from Neoplan were expected to be delivered, but there were massive project delays due to technical problems in realizing the gas production and local authorities worrying about the risks of gas due to the absence of appropriate standards, which the limited experience of handling gas vehicles in Sweden demonstrated. In addition, the participants in the project demanded increased coordination of Swedish and international standards in relation to gas in the future. Despite the delays, the first experiences with the gas vehicles were very positive and the bus companies wanted to expand the trial. Other actors came forward to show an interest in converting conventional vehicles to biogas. Due to the early phase of the project, detailed evaluations had to wait. However, there were indications of lower emissions for biogas buses, similar to the results in other biogas projects (Brolin, Rudholm, & Eklund, 1997).

With the increased use of biogas, the problem of standardization expanded: this was not a problem exclusive to the Uppsala trial. With financing from the Swedish Gas Association and the KFB, a working group had been set up in the early 1990s to take on the development of a specification for biogas in Sweden. The Swedish Gas Technical Centre (Svenskt Gastekniskt Center) led the group. Additional actors in the group were the consultant company VBB Viak, Vattenfall Energy Systems, the public transport company Näckros buss (previously LITA) and a non-profit association aiming to further biogas development – the Swedish Biogas Association (Svenska Biogasföreningen). The novelty of vehicle biogas and the related upgrading technology made standards development a slow process. Another problem was the variable quality of biogas, which affected the combustion energy output (the Wobbe-index). This was also a problem for natural gas. These problems prevented the development of emission standards for gas vehicles. The limited biogas vehicle market, which existed only in Sweden, made it difficult to push for a standardization of biogas on its own. By linking up with existing natural gas standards, the group hoped to facilitate the introduction of biogas and resolve problems such as the varying Wobbe-index and lack of emission standards for all types of gas-driven vehicles (Maltesson, 1997).

A 1995 study (Brolin, Hagelberg, & Norström, 1995) states that biogas was not yet competitive due to the high cost of biogas vehicles, but that prices were expected to decrease in the future. This had not changed at the end of this period, since biogas was still dependent on protection in terms of tax exemptions, subsidies and other support in the form of infrastructure and engine technology from their natural gas partners. Nevertheless, the positive experience of experiments and scientific evaluations contributed to the conclusion of the Alternative Fuel Commission (Alternativbränsleutredningen, 1996) that biogas was the most environmentally friendly fuel option in 1996,[65] and this is likely to have contributed to its development throughout this period.

The variety of gas experiments that emerged in the wake of the introduction of natural gas to Sweden resulted in the development of gas vehicles, gas distribution locations and the use of natural and biogas (see Table 23). Table 23 shows that gas consumption increased more than eleven-fold between 1996 and 1997. However, natural gas consumption was still dominating the gas propulsion sector.

---

[65] Biogas was followed by bio-ethanol, bio-methanol, RME/DME, natural gas and last RME as a mix in diesel. However, they argue that there is much uncertainty about RME and DME since there was not sufficient emission data to be able to judge their potential (Egebäck och Westerholm, 1997).

Year	1995	1996	1997
No of vehicles			
Personal	20	35	395
Heavy	0	18	35
Buses	24	151	227
Total	44	204	657
No of distribution locations			
Public	1	3	7
Non-public, bus	1	5	7
Total	2	8	14
Sold volume (in 1000 Nm3)			
Natural gas	986	4213	6017
Biogas	0	95	1120
Total	986	4308	7137

Table 23: Number of gas vehicles, distribution locations and volume of fuel sold, 1995-1997

Source: (Energigas Sverige, 2011)

7.3.2. Biogas SNM analysis, 1986-1997

Gas 1986-1997									
	1986 -1989	1990	1991	1992	1993	1994	1995	1996	1997
Natural gas	3 buses Malmö								
			20 buses Gtb						
							5 cars Gtb		
								50 cars Malmö	
Biogas				5 buses Linköping					48 buses
									2 cars Linköping
				Plant Linköping					Add. Plant
				Plant Gtb					
						5-10 vehicles Gtb			
								3 buses Trollhättan	
								2 trucks Trollhättan	
								cars Trollhättan	
								Plant Trollhättan	
								20-61 cars Sthlm	
								Plant Sthlm	
								6 buses Uppsala	
								6 cars Uppsala	
								1 truck Uppsala	
								Plant Uppsala	

Table 24: Natural gas and biogas development, 1986-1997

Network actors	Biofuel	Expectations	Key experiments	Learning	Socio-technical configurations
Biogas actors: municipalities, their wastewater plants producing biogas and fleets. General gas actors: natural gas suppliers, Volvo and municipal fleets.	Biogas pure use and production	Initial expectation of biogas as a means to implement natural gas shifts to biogas implementation alone due to increased environmental benefits of biogas use, solutions to local waste management and regional development.	Successful biogas production and use in buses. One of the path breaking developments was the feed in of biogas in natural gas infrastructure at the end of the period.	Lessons drawn from natural gas and exploitation of natural gas technology and infrastructure. Initial small technical and social problems resolved. Realization of social benefits of biogas leads to separate niche. Great advances made possible by financial and geographical isolation from natural gas.	Local facilities for biogas upgrading, a bus market niche and selected use in bi-fuel car fleets. Related infrastructure for distribution, storage in place, mainly thanks to natural gas, as well as development of standards which indicate increased niche stability.

There were two *networks* behind biogas development in this period. First, a network supporting gas propulsion in general, such as natural gas suppliers, Volvo and a variety of (mainly public authority) fleets. Second, the biogas network of which the main actors were municipalities, their wastewater plants producing biogas, and fleets such as the municipally owned public transport companies driving on the fuel. The biogas actors were initially part of the general gas network in which the powerful natural gas regime actor was a particular resource. However, once the biogas actors separated from the general gas network in the early 1990s, the broad and strong network actor support declined but actors' activities became more aligned towards biogas development.

The formation of a separate biogas network went hand in hand with a shift from an initial *expectation* that biogas was a means to facilitate the implementation natural gas to the expectation that biogas was a more beneficial technology than natural gas. The expected benefits of biogas referred to its high emission reduction potential of CO_2, but also improvement of local inner city air, the contribution to local waste management by getting rid of local waste in a potentially profitable manner and the potentially positive economic effects for the region as a whole. The municipality of Linköping and its public transport company took the lead in biogas experimentation by initiating biogas upgrading and use in vehicles in the early 1990s. Other municipalities followed Linköping's example with small clusters of biogas production and use in a few Swedish cities as a result. In addition to increasing environmental concerns, the financial support and in particular the decision by the government to stop the natural gas pipeline expansion to avoid competition with biogas were external events that stimulated biogas expectations and further niche development.

Expectations were reinforced by the main *lesson* that biogas upgrading and use in vehicles worked and that it was proved to have better socio-economic and ecological benefits than natural gas. Various lessons (social, technical, institutional) were linked, as exemplified by the adaptation of the production process to reduce smells from the waste being fermented and by upgrading biogas to natural gas standard in order to benefit from similar already developed infrastructure and engine technology. This was not easy because the gas niche resisted at first. However, at the end of the period the feed in of biogas to the pipelines was accepted in certain parts of the country.

The result of the efforts by biogas actors was a small market niche of public transport buses, and a few small biogas vehicle fleets with bi-fuel engines (see Table 24). The vehicles were supported by fuel from a few local biogas production and upgrading facilities. Gas storage and distribution infrastructure and related standards were adapted from natural gas. This indicates a reasonable degree of niche development, although many standards were not officially recognized.

7.3.3. The development of a biogas discourse, 1986-1997

The way in which biogas became an interesting transport fuel option is related to the growth of the natural gas discourse. Hence, this section covers general (natural) gas discourse developments, with particular attention to the biogas discourse.

According to Moberg (1991), natural gas proponents were successful in promoting natural gas as a potential alternative to both fossil and nuclear energy. The second oil crisis and thus the growing oil substitution discourse as well as the anti-nuclear discourse in the late 1970s contributed to the decision to implement natural gas. In addition, natural gas proponents argued that natural gas emissions of sulphur and heavy metals were very low compared to other fossil fuels and wood. In addition, the CO_2 emissions were argued to be 25-40% lower than for both oil and coal (Moberg, 1991). By these means, they successfully embedded the natural gas discourse in the general environmental discourse as well. Because of the growing popularity of natural gas, the government decided to run a natural gas pipeline from Denmark to Malmö in 1981, which started delivering natural gas in 1985 (Statens energiverk, 1987b).

This decision may also have been influenced by the alternative transport fuel debates. As indicated in the section on methanol, natural gas was a potential feedstock for methanol production, which was the dominant alternative fuel during the 1970s and early 1980s. Natural gas became even more interesting when it became clear that bio-based methanol was difficult to realize in the short term (see the section on methanol). In the 1980s, there were also environmental arguments for direct use of natural gas in vehicles. For instance, the scientists at the Energy Centre at Chalmers Technical University argued that using natural gas directly would save the energy lost when converting it to methanol. Moreover, they argued that emission reduction was better when using natural gas compared to methanol (Ny Teknik, 1980). Hence, by linking up with the environmental discourse and to some extent positioning against methanol, the gas discourse[66] entered the transport sector as an alternative fuel.

The availability of a gas discourse and natural gas in Malmö stimulated the city of Malmö to start the first vehicle trial with natural gas. In line with the discourse, the intention was to reduce harmful emissions (Ekelund, 1998). In addition, a number of other actors including Gothenburg, Stockholm and other Nordic capitals, as well as the vehicle companies SCANIA and Volvo started a cooperation in order to promote gas as an environmental vehicle propulsion. With support from the Nordic cooperation, Volvo and Scania started to investigate the emission potential of gas engines. Dissemination of a variety of studies showing large emission reductions with gas engines in buses led to great support for the gas discourse and orders for gas buses in Sweden and internationally (Ekelund et al., 1993). While Scania focused on the development of gas buses only, Volvo took the lead in the development of both gas buses and cars. Volvo introduced a bi-fuel car, able to run on gas and gasoline, on the Swedish market in 1995 (Sandén & Jonasson, 2005). In this way Volvo became one of the main promoters, next to the Nordic cities, of the gas discourse in the Swedish alternative vehicle sector.

Because of the planned construction route of the natural gas pipeline from Malmö to Gothenburg and further to Stockholm, municipalities in mid-Sweden saw reasons to prepare for the coming gas distribution. Part of these preparations was the creation of an infrastructure for gas vehicles. As in the case of the Malmö trial, the motive for this was emission reductions. Since the natural gas was not yet available, the municipalities decided to

[66] From here on I will refer to the 'gas discourse' in terms of support for gas as propulsion for vehicles if not indicated otherwise.

upgrade the biogas from the municipal sewage treatment installations to natural gas standard. Developing biogas in the wake of the natural gas discourse, exploiting its standards and promises, enabled the development of a biogas discourse (Ekelund, 1998; Kullbjer, 1995). The increasing demand for an environmentally friendly fuel, which in particular would reduce CO_2 emissions, led to increased criticism of natural gas and presented biogas as a more suitable alternative. The biogas actors used a stepping stone argument, promoting biogas as a 'long-term alternative to natural gas' (Ekelund et al., 1993: 40).

Meanwhile, an increasing number of municipalities started to promote biogas for its potential environmental and economic benefits. While the technology was not profitable as such, the municipal responsibility to recycle waste and reduce emissions from public transport gave them sufficient incentives to promote biogas production. This referred to the idea that the recycling of waste could be done more economically by processing it to products like biogas and bio-fertilizer that could replace expensive and imported fossil products. In turn, the biogas would contribute to the reduction of local as well as global emissions by collecting the methane when processing waste to biogas and using it for propulsion in the transport sector (Brolin et al., 1995; Lothigius, 1997; Ekelund, 1998).[67] Scientists and project managers stated that the collection of methane emissions was one of the great benefits of biogas. Methane is a much more dangerous greenhouse gas than CO_2 that is released when biological matter decomposes. Because waste managers released much of the methane into the atmosphere or torched it to avoid release, the collection and processing of the methane for use as a vehicle fuel contributed greatly to the reduction of greenhouse gas emissions (Egebäck & Westerholm, 1997; Brolin et al., 1995). Biogas proponents criticized natural gas for contributing to methane release and thus having an environmental downside. Methane release occurs in the process of natural gas extraction from the ground (Statens energiverk, 1990).

In addition to the main biogas promoters, municipalities introduced a biogas discourse referring to the benefits for regional development and the environment, and farmer interests as part of the bioenergy and ethanol coalitions contributed to the discourse. They argued that biogas had better environmental properties and fitted better with current environmental policy than natural gas. Another recognizable argument was that biogas would contribute to increased employment in the countryside and an improved Swedish trade balance, which indicates a link with the upcoming regional development discourse. A final argument that the bioenergy and ethanol proponents added to the discourse was that biogas had a better fit with the oil substitution/emergency fuel discourse since it was based on domestic feedstock, unlike the imported natural gas option (Mared, 1990; Bengtsson, 1991).

Increased recognition of the qualities of biogas from a variety of actor coalitions meant that the planned expansion of the natural gas pipeline from Gothenburg to Stockholm was increasingly seen as a threat to future biogas development (Bengtsson, 1991; Statens energiverk, 1990; Mared, 1990). The 1991 three-party agreement withdrew plans to expand the natural gas pipeline to avoid competition with biomass options, in particular biogas (Carlsson & Molin, 1991).

The developments described above show that the biogas coalition made strategic use of the advances made by the natural gas discourse by linking up with the discourse and later distancing itself from it. The biogas coalition applied a similar strategy in relation to the ethanol discourse. An example of this was the large-scale Biofuel Programme. Due to political circumstances, a strategic ethanol coalition of actors and a relatively strong ethanol

[67] These goals are motivated by the economic responsibility of the municipalities and provinces in Sweden in general and the increasingly decentralized environmental policy, meaning that municipalities had to reach certain environmental goals based on Agenda 21, agreed at the UN Rio Earth Summit (Fallde et al., 2007).

discourse the government set up a Biofuel Programme in 1992 with a focus on ethanol development and implementation (see the ethanol section above). Despite the ethanol focus, successful lobbying by the biogas coalition led to Biofuel Programme funds for both biogas and ethanol from 1993 onwards (see KFB, 1994). This however, did not seem to bother the ethanol proponents who, as is mentioned above, supported biogas.

By collaborating and benefitting from both natural gas and ethanol developments, the biogas discourse grew in popularity and so did the implementation of biogas upgrading plants, central filling stations and biogas buses, and eventually biogas propelled bi-fuel cars. The popularity was in particular a result of successful biogas promotion by Clean Vehicles Stockholm, a local organization for environmental vehicles in Stockholm that achieved a breakthrough in biogas expansion in Stockholm after 1996 (Rahm et al., 1997).

The tax on natural gas and biogas in Sweden disregarded use in vehicles or for energy and was lower than for fossil vehicle fuels (Carlsson & Nygren, 1994). However, when Sweden joined the EU in 1995 and had to conform to EU policy, biogas actors feared they would lose their tax exemption. The EU Mineral oil directive allowed for a temporary tax exemption for fuels like ethanol and biodiesel, but not biogas. However, the strength of the biogas discourse led to determined government negotiations at the EU level in order to make an exception for biogas (Alternativbränsleutredningen, 1996: 24; see also Carlsson & Nygren, 1994). The negotiations were successful; all member states accepted the Swedish exception to give a general tax exemption to biogas (Alternativbränsleutredningen, 1996: 308). Consequently, biogas had a more beneficial and institutionalized tax exemption than other biofuels, which had to fit in with the scheme of temporary exemptions within the EU Mineral oil directive

While municipalities, their local transport companies and local sewage plants (sometimes waste/landfill managers) were the central proponents behind the biogas discourse, farmers became increasingly involved in the lobby at the end of this period. This was partly due to the farmers' motivation for regional development as mentioned above. An argument added to the biogas discourse in the last years of this period was the benefits of by-products such as bio-fertilizers, which contributed to reduce emissions and substituted for imported fossil based fertilizers (Statens energiverk, 1990; Månsson, 1998). Moreover, due to the limited biogas supply from waste, the Swedish Institute for Agricultural Engineering started to research the use of agricultural crops for biogas production. Throughout the 1990s, scientific reports increasingly argued that grass crops cultivated on surplus farm land were a good feedstock for biogas production. It was good for the environment due to reduced emissions, substituting fossil fuels with biogas use, and good for the soil and thus also for farmers (Månsson, 1998).

As to arguments against biogas development, researchers pointed out the high cost of vehicle technology and infrastructure as the main disadvantage (Brolin et al., 1995). Other arguments highlighted the limitations on suitable, cheap and accessible raw material for biogas in comparison to other fuels such as ethanol, which meant that the fuel would be no more than a niche fuel reserved for heavy vehicles (Alternativbränsleutredningen, 1996).

Moreover, while natural gas proponents had been cooperative with biogas promoters and still wanted to give the impression they were part of the same lobby, they became less supportive once the biogas discourse gained more support based on the discourse that it was more environmentally benign. According to Ekelund (Ekelund, 1998), one indication of this trend was the refusal to allow biogas in the natural gas pipeline as late as in 1997, even though there was no technical reason not to do so. Another temporary threat to the general gas discourse was when bi-fuel vehicle production ceased at Volvo in 1997, despite its successful take-off since its introduction in 1995. Nevertheless, the cessation was due to internal problems at Volvo and by September 1997 a second generation of bi-fuel cars was being marketed (Sandén & Jonasson, 2005).

The increasing growth of the environmental discourse on CO_2 reductions in the 1990s due to the Rio de Janeiro declaration in 1994 and the upcoming Kyoto Protocol in 1997, motivated the search for a biofuel with the highest CO_2 efficiency in relation to costs, as well as other reductions of emissions that harm health and the environment. As is outlined in the ethanol section, the classification of biogas as the most environmentally benign fuel alternative was outlined in 1996 by the Alternative Fuels Commission (Alternativbränsleutredningen, 1996). In this way, the biogas discourse gained increased legitimacy and support, which is particularly visible in the section describing developments post-1997.

7.3.4. Biogas discourse analysis, 1986-1997

General policy developments affecting natural gas/biogas development					
Policy	**Level**	**Year**	**Type**	**Size SEK**	**Explanation**
Energy tax exemption	government	1993-1994	Regulation		Biogas exempted from tax in early 1990s
TFB/KFB Biofuel pro-gramme	Government, industry, municipalities etc.	1993-1997	R&D and demo	Total 315 million, of which govern-ment 120 million.	R&D and demonstration programme starting in 1992 and designed for ethanol. In 1993 decided that biogas would benefit from the programme. For funding, 50% co-financing necessary.
Rio de Janeiro declaration	UN	1992	Agreement	?	Non-binding agreement to stabilize CO_2 emissions in 2000 to the level of 1990.
Biogas tax exemptions	EU, government	1995-	Regulation	?	General tax exemptions after negotiations with the EU.
'Green folkhem'	Government	1996-2005	Vision	?	Prime minister states that he intends to make Sweden leader in environmental development.
Kyoto agreement	UN	1997	Agreement	?	Non-binding agreement on CO_2 reduction by 2012 with 1990 as reference value.
Natural gas/biogas initiatives					
Initiatives	**Governance level**	**Year**	**Type**	**Size SEK**	**Explanation**
Gas buses Malmö	Municipality	1986	Field trial	?	3 gas buses and gas distribution was set up in Malmö
Nordic Gas Bus Project	Nordic governments	1988-90		?	Project initiated in 1988 by Nordic Board of Ministries
	Nordic governments, private sector		R&D	Total 10 million, Nordisk Industrifond main financer	1st phase: develop low emission natural gas engines based on SCANIA and Volvo technology
	Nordic governments, municipality, private sector		R&D, commu-nication	Total 6.27 million. Nordisk Industrifond main financer.	2nd phase: eliminate barriers that hinder intro gas in vehicles by informative studies and development of standards
Gas buses Gothen-burg	Municipality	1991-	Field trial	?	1991-1992: 20 Volvo natural gas buses in Gothenburg, trial continues after initial period.
bi-fuel vehicles	Municipality	1995-	Field trial	?	5 Volvo bi-fuel vehicles with two tanks (gasoline and gas) in Gothenburg.
	Municipality, private actors	1996-	Field trial	?	50 Volvo bi-fuel vehicles run by taxi company Malmö and Volvo.
	Industry	1996-	Field trial	?	Total of 160-170 Volvo bi-fuel vehicles due to additional orders from Stockholm and abroad.

Policy	Level	Year	Type	Size SEK	Explanation
Linköping biogas buses and plant	Government, Municipality	1992-	Field trial	Total 16.3M, of which LITA contributed 8 million.	5 Scania buses on biogas in Linköping, including pump and upgrading installation at existing sewage plant.
	Government (KFB), municipality	1996-		?	1996 set up Linköping's Inner City Bus Programme. Aims to develop biogas market. Experiments follow from 1997 on
	Government, Municipality, private actors	1997-	Plant	?	1997: Plant Linköpings Biogas (today: Svensk Biogas) and upgrading
Trollhättan biogas buses	Government, municipality, industry	1990-	Feasibility study	Total budget 30.7M, of which KFB 13.7M	1990: feasibility study for biogas project
		1996-	Field trial		1996: 3 buses start running on biogas. Additional trials 1997 onwards covered by project budget.
Gothen-burg biogas plant and buses	Municipality (Gryab)	1990-	Field trial	Construction costs 88 million financed by Gryab.	1990: set up anaerobic installation at Gryab (sewage plant). 1992: biogas upgrading facility added to plant.
	Municipality	1992-	Field trial	?	1992: policy aim to increase biogas production and use.
		1994-	Field trial	?	1994: set up refuelling station, 5-10 of Gryab's vehicles run on biogas
Stockholm biogas	Stockholm City together with other local cities	1994-	Project	Post 1996: EU Thermie grant	Project 'Clean Vehicles Stockholm', 1996 decided to implement 300 environmental vehicles before 1997, of which 180 should be biogas.
	Municipality, private companies	1996-	Field trial	?	1996: Biogas production and upgrading unit (pilot) Bromma, biogas refuelling station, and 61 bi-fuel cars (Volvo, VW, BMW) for local authorities in 1997
Uppsala biogas	Municipality, academic institutes	1995-	Field trial	?	Large-scale gasification installation. 1996: Biogas upgrading installation, refuelling system, 6 buses (Neoplan), 6 bi-fuel cars (Volvo, VW) for local authorities, 1 garbage truck (New Zeeland) expansions planned for 1997.

Table 25: Natural gas- and Biogas-related policy development, 1985-1997

Biofuel	**Discourse**	**Mobilization/ impact of wider discourses, events and policies.**	**Discourse coalition**	**Target audience**	**Key activities, strategies**	**Resulting space/ policy creation or disruption**
Biogas production and pure use	Initially biogas as bridging technology to natural gas. 1990s onwards: biogas as more environmental gas propulsion that could aid local economic development and waste management.	Initial embedding in (natural) gas discourse, later increased embedding in environmental (mainly local) and regional development discourse. EU membership implied temporal threat of discontinued tax exemption.	Initially driven by natural gas actors. Later driven by biogas actors: Linköping municipality, related public transport company and temporal involvement of national politicians.	Initially the government and later the EU and wider public.	Lobbying through: media, scientific reports, in national and EU policy debate. Actors were particularly strategic in timing and tuning lobby activities to benefit most from gas and ethanol discourses.	Benefit from natural gas standards, general tax exemptions at the national and EU level and subsidies from Biofuel pro-gramme

Initially, the general gas discourse actors presented biogas as a bridge to the implementation of environmentally friendly natural gas fuel in vehicles. In the early 1990s, an individual biogas discourse evolved that presented biogas as a more environmentally friendly alternative than natural gas that could also aid local economic development and local waste recycling practices. The idea of biogas as the 'long-term alternative to natural gas' reflects the way in which this discourse took a stand against the initial gas discourse. The individual biogas discourse was aided by increased embedding in the local and global environmental discourse and the regional development discourse.

The biogas coalition was led by municipally owned biogas producers and public transport companies (LITA). In line with the articulated discourses, these actors were initially part of a wider gas coalition supported by various natural gas actors and the vehicle industry. The development of an individual biogas discourse was a result of biogas actors stepping out from the general gas coalitions. Biogas actors used conventional lobbying strategies by reaching out in the media, scientific reports and the national and EU policy debate; they were also strategic in timing and tuning their lobbying activities to other events and discourses to gain the most benefit. An example of the latter were the close ties with the general natural gas discourse in order to continue benefitting from their developed legitimacy and standards even after an individual biogas discourse was formed. Another example was the integration of biogas into the Biofuel Programme despite the fact that it was a result of ethanol lobbying activities. This strategic game is likely to explain much of the biogas support, since the small and homogeneous group driving the biogas coalition did not have much power to influence the general policy agenda.

The successful development of the biogas discourse in the wake of both natural gas and ethanol developments contributed to high levels of policy support. Natural gas actors provided suitable infrastructure, vehicles and standards, and ethanol actors paved the way for biogas subsidies from the large Biofuel Programme. In addition, the government aided biogas market development by preventing natural gas expansion and persuaded the EU to allow a general biogas tax exemption while other biofuels gained only temporary tax exemptions. However, there were drawbacks in the support. Biogas and ethanol were not only cooperating, they were also potential competitors. Examples of this was the argument by ethanol actors that biogas, unlike ethanol, could only be a niche fuel due to the limited suitable feedstock.

7.4. THE SLOW DEVELOPMENT OF BIODIESEL, 1980-1997

This section describes the initial interest in rapeseed oil and the introduction of biodiesel production and use, in this case RME, in the period 1980-1997. Due to the limited discourse development in this period, this section focuses on bio oil and biodiesel niche developments only, followed by an SNM analysis. In chapter 8 I present both the biodiesel niche and policy developments, including analyses.

7.4.1. PVO and biodiesel niche development, 1980-1997

As a result of the oil crisis of the 1970s, farmers became interested in rapeseed oil diesel as a potential substitute for fossil diesel. The Swedish Oil-Seed Producers' Association carried out one of the first trials with pure vegetable oil (PVO) based on rapeseed. The government subsidized these trials (Swedish Commission for Oil Substitution, 1982:100). In addition to the trials run by the farmers' association, a government institute, the National Testing Institute for Agricultural Machinery (Statens Maskinprovningar) carried out a PVO trial with six tractors with diesel engines in 1981-1984. Problems arose due to the increased viscosity of rapeseed oil in cold weather. To resolve these problems, the National Testing Institute used a 33% mix of pure rapeseed oil in diesel, more commonly called R33. Other ways to avoid the clogging of the rapeseed oil was the use of additives, pre-heating of the rapeseed fuel and engine systems and the conversion of the rapeseed oil to a biodiesel – RME (Motoralkoholkommittén, 1986a: 87-88). The decision to carry out trials with R33 was not a coincidence since only trials with PVO blends above 30% were exempted from tax by the mineral oil tax regulation in force since 1961. However, full tax exemption was only applicable for imported blends. If the mineral oil was mixed with 33% PVO in Sweden, the mineral oil was to be taxed (Carlsson & Nygren, 1994). After running the R33 tractor trial for a period of 8000 hours with hardly any complications, the National Testing Institute concluded that the trial was successful. Contemporaneous PVO trials in other European countries drew similar conclusions. The ability of the fuel to reduce emissions was not clear due to limited research on this matter (Motoralkoholkommittén, 1986a: 87-88).

Next to scarcity of oil, the increasing economic problems of and surplus production in the agricultural sector became issues that stimulated the need for new markets such as biofuels in the 1980s (Motoralkoholkommittén, 1986a). Drawbacks of pure rapeseed oil were the need for a large agricultural area, competition with edible oils and its inability to fit with Swedish fuel standards. An alternative was biodiesel from rapeseed, RME, which was a fit with the fuel standards and worked better in diesel engines, but had a much higher cost than PVO and other alternative fuels. This was due to the conversion process, transesterification, of PVO to biodiesel (SDAB, 1982: 97). This is likely to explain why PVO and biodiesel projects did not gain the subsidies that methanol and ethanol did.

However, like all other biofuels, the government exempted PVO and RME from the CO_2 tax that was set up in 1990 (Finansdepartementet, 1990). This tax is likely to have triggered what Carlsson and Nygren (1994) observed as an increased interest in using vegetable oil as a vehicle fuel in the early 1990s. In August 1993, the government altered the mineral oil tax from 1961 to enable tax exemptions for all vegetable oil fuels, regardless of the share used in mineral oil. All mineral oil was taxed, with the exception of small blends under 5% (Carlsson & Nygren, 1994). By these means, imported and domestic PVO and biodiesel could compete on the same terms, which stimulated domestic production.

In 1993, the farmer owned company Svenskt Ecobränsle was the first to produce small amounts of RME and sell it to a few pioneers. In 1995 their first RME factory was built in Stridsvig in the region of Skåne. The production of RME in 1995 coincides with what Sandebring (2004) sees as the introduction of RME sales on the Swedish market. According to the statistics he presents (see Table 26) the consumption of RME stayed at a steady level of 7500-8000 m^3 per year until 2003. For the years 1995-1997, RME use corresponded to almost two-thirds of the most popular biofuel – ethanol. Nevertheless, this was not based on domestic production alone. Approximately 90% of the sales were of imported RME (Sandebring, 2004).

Year	**1995- 1997**	**1998**
RME in m³	16000	7500

Table 26: Sales of RME, 1995-1998
(Sandebring, 2004)

The most common use of RME in Sweden in the mid-1990s was in the form of blends of 5% or 35%. The 5% blend was most common, used in outdoor agricultural or forestry machines and vehicles. The 35% blend was mainly used together with paraffin oil for indoor work-related vehicles (Alternativbränsleutredningen, 1996). In 1996, a 2% blend was introduced in addition to the other blends (Ecobränsle, 2012). Blends were popular partly because no engine modifications were necessary. Corrosion occurs with pure RME use, which means that rubbers in the diesel engine have to be replaced (Alternativbränsleutredningen, 1996).

Despite the relatively high use of RME, there is hardly any information about individual experiments. For instance, the Alternative Fuel Commission only referred to one RME trial – a six-month field trial with low blend RME in forest and agricultural vehicles by the farmer company Lantmännen Energi AB in 1995. The trial showed no engine problems and the company reported it as successful. The farmer company promoted both low blend and high blend use in the future. They related this to the fact that German car manufacturers had verified their new diesel vehicle models, produced in 1995, as suitable for the use of both low and high RME blends. However, the German vehicle guarantees for RME use were not valid in Sweden (Alternativbränsleutredningen, 1996).

The institutional barriers that did not accept German vehicle guarantees and the fact that RME was mainly used in niches with limited visibility is likely to have limited the expansion of the niche. Additional barriers were Swedish EU membership in 1995. Persson and Åsbrink (1997) indicate that the need to adopt the temporary EU pilot project exemptions for biofuels created a fear of discontinued tax exemptions within the biofuel community. However, the Swedish government insured that the tax exemptions for RME were continued as usual despite the EU tax scheme. Moreover, according to Sandén and Jonasson (2005), rapeseed farming became less profitable after initial Swedish financial support for rapeseed cultivation was withdrawn due to adjustments to EU standards. This coincides with what Sandebring (2004) observes as a dip in domestic rapeseed cultivation in the mid-1990s. However, he argued that RME imports kept the experiments going.

The RME used was not all about blends. In the mid-1990s oil distribution companies engaged in pure RME distribution. One example was the Norwegian fuel distribution company Statoil, which in 1996 started to distribute pure RME in two pilot filling stations in Stockholm. According to Anna Persson, a project leader for alternative fuels at Statoil, there was a major demand, which led Statoil to make plans to expand the trial to the south of Sweden. The main customers in the RME pilot were municipalities, taxi companies and delivery firms. The fuel distribution company OK followed Statoil's example and set up four RME distribution locations in Stockholm in 1997 (Miljörapporten, 1997b). The large demand for pure RME can be linked to the popularity of RME abroad, as indicated by the German biodiesel vehicles mentioned above.

However, scientific investigations did not show very positive results for pure RME use. Several scientific accounts from 1994 onwards argued that pure RME use created more NO_x emissions than the use of fossil diesel (see Egebäck & Westerholm, 1997; Alternativbränsleutredningen, 1996). NUTEK raised the issue of large nitrous oxide emissions due to the need for heavy fertilizer use in rapeseed cultivation (Kommunikationskommittén, 1997: appendix). In addition, it was generally acknowledged that the agricultural land on which oil plants could be cultivated was limited in Sweden (Alternativbränsleutredningen, 1996). Due to competition with other uses of rapeseed oil, a scenario from KFB, NUTEK and SIKA in 1997 indicated that 35 000 m^3 could be produced which corresponded to about 1% of total diesel fuel used (Månsson, 1998). This contributed to the idea of RME as only a niche fuel.

The RME critique was mainly directed towards pure RME use. Towards the end of the period, there were increasingly positive accounts of low blend RME use, which are likely to have boosted low blend expectations in the coming period. For instance, the Alternative Fuel Commission (Alternativbränsleutredningen, 1996) recommended using low blend RME in diesel as a means to reduce CO_2 emissions. By these means, domestic RME could be used despite the restricted cultivation area (Miljörapporten, 1997a). In addition, the budget bill for 1998 (Persson & Åsbrink, 1997) suggested continued CO_2 tax exemptions for all biofuels including RME (Persson & Åsbrink, 1997: 173-174).

7.4.2. PVO and biodiesel SNM analysis, 1980-1997

Year	1980	1981	1982	1983	1984	1985 - 1989	1990	1991	1992	1993	1994	1995	1996	1997
PVO	PVO agricultural vehicles													
		tractors R33												
RME							R5 agricultural/forest vehicles							
							R35 indoor fleets							
													RME taxis, municipalities	
							Import							
										Ecobränsle		Plant		
													R100 pumps	

Table 27: PVO and biodiesel development, 1980-1997

Network actors	Biofuel	Expectations	Key experiments	Learning	Socio-technical configurations
Farmer orgs, municipalities and other private fleet owners, oil distribution companies. Great turnover of actors over time	PVO and RME, blends and pure	Initial high blend PVO promise replaced by low blend RME promise. RME was considered particularly suitable for heavy vehicle use and, to have environmental benefits and a market for agricultural surplus	Limited experiments with various blends in agricultural and other fleets. Only temporary interest in pure fuels.	The learning was mainly technical, related to the better fit of RME in comparison to PVO and the way in which RME could be applied to deliver environmental benefits. A financial lesson was the dependence on subsidies for fuel expansion.	RME production plant and imports sustain small high and low blend niches. Niche weak due to weak network and persistent criticism of environmental qualities.

Farmers' organizations were the leading biodiesel *actors* that initiated vegetable oil fuel experiments, which focused on RME at an early stage. Farmers and other private fleet owners were early RME users. Both focused on various RME blends, of around 30% and lower. In the mid-1990s, farmers set up the first small scale RME factory to complement the RME imports for the expanding low blend market. In addition, fuel distributors, importers and additional fleet owners (taxi, municipal fleets) started single pure RME fuel experiments. This contributed to a broader network in the late 1990s, but a slightly decreased alignment as a result of increased diversification with regard to what RME use was expected to produce the best emissions reductions. Expectations regarding the suitability of RME fuels had been shifting over time.

The oil shortages of the 1970s stimulated *expectations* for pure vegetable oil and RME as potential means to reduce dependency on expensive and unreliable fossil fuels. These vegetable oil fuels were also expected to reduce emissions and create market opportunities for the agricultural sector in the 1980s. This explains the central role of agricultural actors in the RME network. After initial PVO experiments indicating engine problems due to high viscosity, the promise shifted to RME alone. Expectations for RME use were initially directed to 33% blends, which in the 1990s shifted to include low blends and pure fuel promise. The pure fuel promise was linked to positive developments abroad and in particular the acceptance of RME use in German vehicle brands. The main *lessons* from the experiments in this period related to the benefits of RME use in comparison to bio oil, but also the benefits of low blend instead of high blend use. The latter related to the fact that low blend RME did not require any engine modifications and was argued to have better environmental effects and meet the domestic feedstock availability criterion better than pure use.

RME development was particularly slow, partly related to the low level of government support in comparison to other biofuels. In the 1990s, RME gained tax exemptions but no other visible financing. The fact that RME was the second-biggest biofuel at the end of this period (see Figure 13) is impressive, given the relatively weak network, low financial support and low visibility of experiments. This low visibility may partly be explained by the fact that the fuel was used as a low blend that did not require adjustments of infrastructure and engines and the fact that the domestic fuel production was for private use for farmers alone, while the great majority of the fuel used was imported. Despite successful market introduction in the latter part of the 1990s the limited technology and infrastructure investment shows rather weak niche stability, which makes the niche vulnerable. This limited stability was also reflected in the limited standardization that was visible in the inability to insure German biodiesel cars in Sweden.

7.5. GENERAL BIOFUEL CONCLUSIONS, 1971-1997

This section concludes biofuel developments in the period 1971-1997. First I present the SNM conclusions and, second, the discourse conclusions.

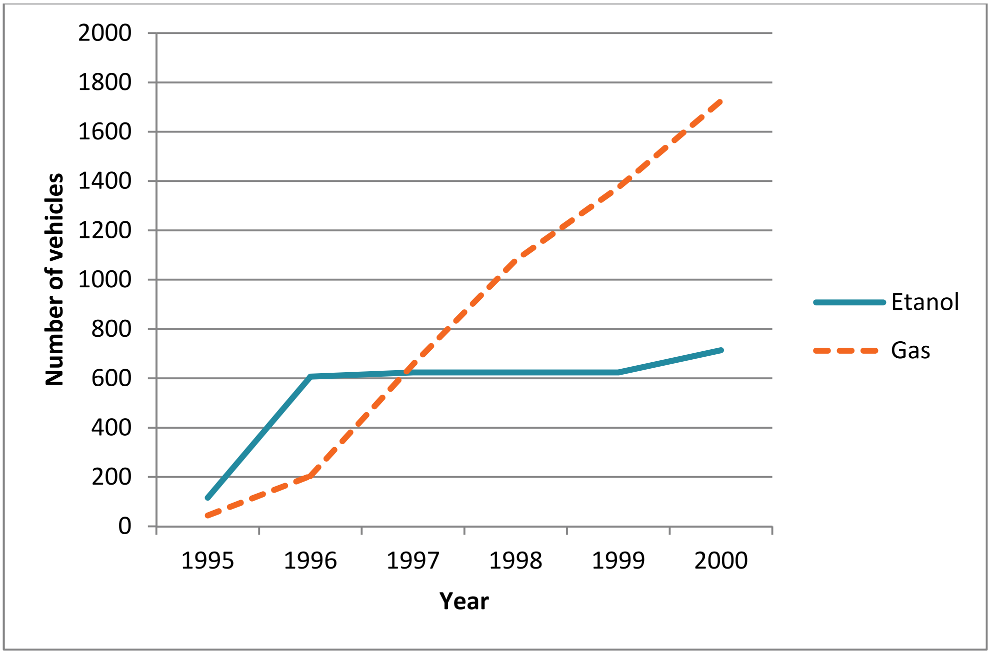

Figure 12: Number of ethanol and gas vehicles, 1995-1997

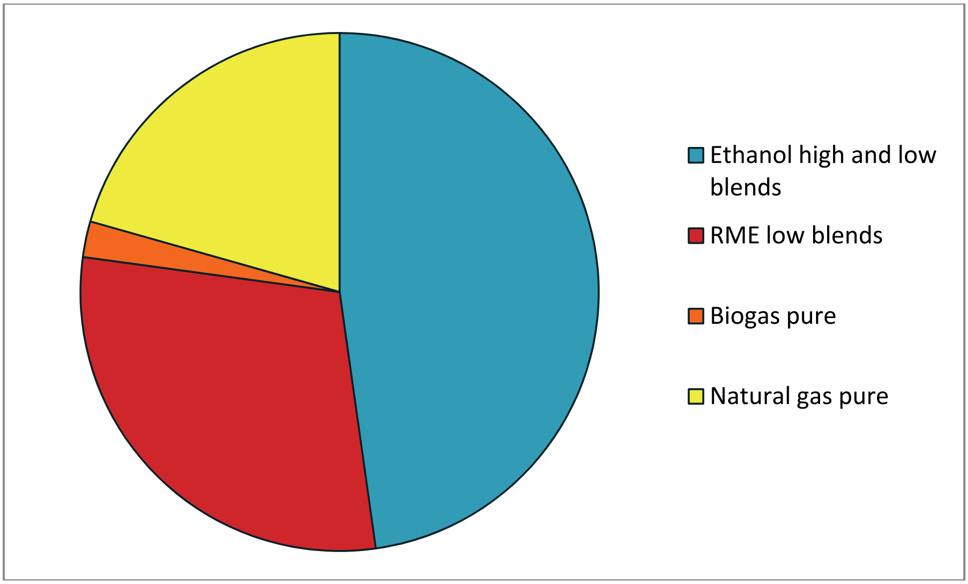

Figure 13: Total alternative fuel sales, 1995-1997

7.5.1. Conclusions: biofuel niche development

Despite a dip in the 1980s, the biofuel niche developed successively in this period (see Figure 12). Looking at the development of individual biofuels, a methanol technology niche was substituted by ethanol in the mid-1980s which became a market niche. In parallel with ethanol development, natural gas was introduced in Sweden through which the biogas niche evolved. A niche that remained at the periphery was RME, despite a relatively large degree of fuel use.

Consistent with the SNM literature, the positive development of early methanol, ethanol and biogas went hand in hand with successively higher financial support and positive network development, and expectations and learning mutually reinforcing each other. The withdrawal of the methanol niche and the slow start of RME indicates an opposite development pattern with weaknesses or limitations in the dynamics of the internal niche development processes and financial support.

A pattern of expectations that can be noted for all niches are the expectations related to the oil substitution potential in the 1970s and later to the expected ability to meet farmers' needs for other regional development, and emission reductions. Successful niches had networks dominated by vehicle producers (Volvo or Saab-SCANIA) and national authorities in the 1970s and 1980s (methanol, ethanol) and dominated by municipalities in the 1990s (ethanol, biogas). In addition, niches that developed successfully throughout this period had prioritized long term experiments with pure or high blend fuel use (biogas, ethanol), while less successful niches had prioritized advanced biofuel production or blends. Potential reasons for this are that pure and high blend field experiments involve relatively higher actor commitment, technology investment, degrees of technology and institutional change, and societal visibility, which increase societal embedding and niche stability in comparison with low blend and R&D on biofuel production.

In all cases, financial support proved decisive for niche development. Hesitant and weak support resulted in slow development, as in the RME case, while continuous and increasing funds resulted in niche development (early methanol, ethanol and biogas), and cessation of funds resulted in the end of experiments (methanol).

7.5.2. Conclusions: biofuel discourse development

In this period three different biofuels discourses emerged and gained protection: methanol, ethanol and biogas. Despite the experience with ethanol as a fuel in the early nineteenth century, methanol was the biofuel discourse that dominated and gained increasing protection until the mid-1980s. This was partly due to the strong vehicle industry and government-led coalition as well as its embedding in the oil substitution discourse. Ethanol was argued to be too expensive and could only gain recognition in the shadow of methanol when both fuels were referred to as alcohols. When the oil substitution discourse vanished in the mid-1980s, the chemical industry and farmers' organizations managed to embed ethanol in both the self-sufficiency and the environmental discourses by presenting it as a bio-based, domestic, small scale and flexible emergency fuel – a discourse with which the methanol discourse could not compete.

After the mid-1980s, ethanol was the dominant biofuel. This was partly thanks to successful lobbying and embedding in dominant discourses related to regional/farmer development and climate change mitigation, but in particular due to a series of exogenous policy decisions. First, as a result of decisions to slow down the expansion of nuclear energy which resulted in more focus on biofuel. Second, negotiations that followed a policy deadlock in 1990 led to large subsidies for ethanol and later also biogas, despite a relatively weak ethanol discourse coalition and discourse support at the time. The strategy of the biogas coalition to 'free-ride' on both the (natural) gas discourse and the ethanol discourse was particularly successful and probably made possible by the underdog position of biogas. Strategies to position alternatives as bridging technologies for more advanced but not yet available options were also frequently applied. Both the methanol and the ethanol discourses contained bridging technology arguments, but also the biogas discourse in relation to natural gas.

8. CONTINUED CONVENTIONAL BIOFUEL MARKET EXPANSION AND MATURING ADVANCED BIOFUELS, 1998-2010

8.1. THE CONTINUED DOMINATION OF ETHANOL, 1998-2010.

This section describes the development of ethanol fuel, which continued to dominate the alternative fuel market in the period 1998-2010. First, I present the development of the ethanol niche followed by an SNM analysis. Second, I describe the political processes that influenced ethanol policy followed by a discourse analysis.

8.1.1. Ethanol niche development, 1998-2010.

Conventional ethanol

In the late 1990s, the agricultural organizations started to plan a wheat ethanol plant. While the previous attempt to build a plant had failed, despite government funding, conditions were different this time. The market demand for ethanol was greater and expected to grow, the need for domestic ethanol supply had been highlighted as crucial for further market expansion and agricultural feedstock was expected to be the only potential feedstock in the short term (Kristenson, 1997b). These expectations were backed by government Commissions. Both the Alternative Fuel Commission (Alternativbränsleutredningen, 1996) and the Communications Committee (Kommunikationskommittén, 1997) advised increased implementation of ethanol, in particular in low blends, to increase CO_2 reductions. In addition, the Communications Committee (Kommunikationskommittén, 1997) argued for government support for a domestic ethanol production plant. When the SLR and the LRF requested a tax exemption, the government promised an exemption for the production of grain ethanol to compensate for the high production costs (Energimagasinet, 1999; Kristenson, 1997b).

As a result of the government's promise to support the plant, the agrarian organizations SLR and LRF set up Agroetanol AB with an equal share of ownership in order to manage the expected grain ethanol plant (Energimagasinet, 1999). Not only Agroetanol was promised tax exemption: the government promised to replace temporary tax exemptions with a general tax exemption for all biofuels as early as 1997 (Persson & Åsbrink, 1997). Although this promise was repeated in several bills in 1998 (Peterson & Lindh, 1998; Persson & Uusman, 1998), the granting of new biofuel tax exemptions ended in 1997 (Riksrevisionen, 2011). Nevertheless, in 1999, the government only granted Agroetanol the promised tax exemption while all other requests were ignored (Miljörapporten, 1999b).

While the government's decision disappointed many biofuel actors, it was positive for Agroetanol AB which finally started construction of the plant in Norrköping. It had estimated the cost of construction to be SEK 450 million. The estimated production cost of each litre of ethanol was SEK 5. The government had given Agroethanol a five-year ethanol tax exemption. The tax exemption was set with the ambition to sell the ethanol at a similar price to gasoline. This time, the uncertainty over the future of the ethanol market that prevented plans to set up a plant in the early 1990s was no longer a barrier. The branch organization of the oil companies, Svenska Petrolium Institutet (SPI), had agreed to buy and distribute 50 000 m^3 ethanol annually. The idea was to use the ethanol as a low 5% blend in all the gasoline distributed in Stockholm, as well as nearby towns such as Södertälje and

Norrköping (Energimagasinet, 1999). The plant was built in 2001 as planned (Energimagasinet, 1999; Lantmännen, 2011).

In parallel with the increase in ethanol supply, ethanol actors made plans for FFV expansion. The municipality of Stockholm and the Environmental Technology Delegation established a Swedish FFV buyers' consortium in 1998 with the ambition of expanding the FFV fleet beyond the first generation Ford Taurus, to include privately owned vehicles as well as the current leased vehicles and to create a better fit between technology and user requirements. The initial partners in the consortium were the City of Stockholm, the Swedish Meteorological and Hydrological Institute (SMHI), Växjö municipality, Borås technical services department, Malmö City traffic department, Helsingborg municipality, Haninge municipality, Örebro housing authority, Örebro municipality, Länsförsäkringar in Malmö, Halland county council and the farmers' organization, LRF. The procurement was led by the Stockholm city project Clean Vehicles Stockholm. The initial focus was on electric vehicles (EVs), but included other alternatives such as hydrogen, gas and ethanol vehicles. In 1997, Clean Vehicles Stockholm reached its short-term goal to replace 300 conventional vehicles with environmentally friendly alternative fuel vehicles in the fleets of the local authorities. The long-term goal was to create a market for clean vehicles (Birath & Pädam, 2010).[68]

While a demand for additional models of environmental vehicles had been expressed by users in previous experiments, a pre-study was carried out in order to gain increased knowledge of potential buyers, their needs and to what extent vehicle producers could meet the defined demands. Volvo and Ford were interested and fitted the demand profile. However, Volvo withdrew at the last minute (Birath & Pädam, 2010). While Birath and Pädam (2010) referred to Volvo's uncertainty over the long-term performance of the their FFV car as the reason for withdrawal, Sandén and Jonasson (2005) indicate that the withdrawal may have been related to the takeover of Volvo cars by Ford in 1999 (Sandén & Jonasson, 2005). The negotiations continued with Ford, which was ready to give a SEK 5 000 discount on the price of a normal Ford Focus. However, Ford would only deliver an order of 4 000 Focus FFVs or more. As in the previous procurement by Örnsköldsvik, the buyers' consortium arranged a marketing campaign to gather interested fleet owners. The campaign resulted in a delivery of 3 000 Focus FFV to various fleets in the summer of 2001, and an additional delivery of 5 000 by 2003 (Birath & Pädam, 2010). A new government programme, the Local Investment Program (LIP), financed part of the procurement (Rehnlund, Blinge, Lundin, Wallin, & Goldstein, 2004). The successful creation of a market niche for company fleets and leasing companies meant that the Clean Vehicles Stockholm project had realized its ethanol vehicle goal. It is also a realization of the Ecotraffic FFV scenario set out in the mid-1990s, outlined above. The creation of a variety of individual fleet owners was a big step for the FFV market, which had previously been limited to one leasing company.

The expansion of flexi fuel leasing vehicles to a variety of fleets was facilitated by a recent government law that lowered the fringe benefit tax, i.e. a tax applied to lease and other work-related cars, for 'environmental class 1' cars propelled by fuels such as ethanol, biogas, natural gas and electricity. By these means, the previously high expense of environmental vehicles became equal to that of conventional vehicles (Statsrådsberedningen, 1999).[69] An additional government support measure was the 20% tax reduction for ethanol

[68] The initial aim to replace 300 of the 1500 vehicles in the fleets of the local authorities by 1997 had already been reached.

[69] To stimulate the use of environmental vehicles, this law adjusted the leasing environmental vehicle fringe benefit value that is relative to the price of the vehicle. Since environmental vehicles are in general more expensive, this

vehicles in 2002 (Persson & Nuder, 2005). Alongside government measures, a facilitating factor was the successful expansion of E85 distribution. Prior to the procurement, only 30 E85 refuelling stations were available in Sweden. However, the fuel distribution companies OK/Q8,[70] Shell and Statoil agreed to supply E85 fuel to meet the FFV's demand. This agreement resulted in eight E85 refuelling points in Stockholm alone by 2000 (Birath & Pädam, 2010). In the whole country, there were as many as 92 E85 refuelling stations in 2003. The LIP programme financed two of these refuelling stations (Rehnlund et al., 2004).

Nevertheless, government support for ethanol trials was inconsistent. The government, which in 1999 had expressed its support for the procurement of 3 000 additional FFVs by Clean Vehicles Stockholm, rejected a request for further support of the ethanol tax exemption in the same year (Miljörapporten, 1999e). However, the government stimulated FFVs by reducing the fringe benefits tax for FFV leasing vehicles from 2000 (Birath & Pädam, 2010).

Despite the vast support for FFVs, ethanol supporters were suspicious of the government incentives. For instance Carstedt, the chairman of the Bio Alcohol Fuel Foundation (BAFF), which was the new name of the SSEU after 1999 (Christensen, 2005), argued that the stimuli for environmental vehicles would not work as an incentive as long as the alternative fuels were more expensive than fossil fuels (Miljörapporten, 2001e). BAFF, which primarily focused on the development of cellulose ethanol, was also interested in expanding the use of ethanol. This was shown in BAFF's goal indicating that total fuel consumption should contain 5% ethanol by 2005 and 15% ethanol by 2010 (Samuelsson, 2004a).

Eventually, the Ministry of Finance agreed a one-year tax exemption on selected biofuels in 2002, but excluded ethanol from this exemption. According to the Ministry of Finance this was because the environmental quality of ethanol was disputed; moreover, it was considered an old technology that did not qualify for pilot project exemptions. Agroetanol AB had nothing to worry about. It had a tax exemption until the end of 2003, and saw policy changes at the EU level – with the plans for a Biofuel directive – as potential for continued tax exemptions from 2003. However, the general incentives to start other ethanol production facilities were non-existent and companies that had run out of old tax-exemptions had no other choice than to tax the ethanol (Miljörapporten, 2001a). According to the magazine Miljörapporten, three years after the tax exemptions were ended, sales of E85 had reduced by three-quarters (Miljörapporten, 2001e). The increase in FFVs did not necessarily increase the demand for ethanol, since the flexi fuel technology enabled these vehicles to run on gasoline as well, which let FFV owners choose the cheapest fuel alternative.

The expansion of ethanol use in gasoline was also hampered by the common fuel specification that the EU implemented in 2000. In the late 1990s, an increasing number of experiments with E10 to E20 ethanol mixes in gasoline were introduced by oil distribution companies. The fuel distribution company OK, later OK/Q8, was a pioneer that introduced a low blend of 10% ethanol in all its gasoline in 1997 (SEKAB, 2008a). The common fuel specification implemented by the EU in 2000 did not accept an ethanol mix in gasoline above 5%. Many projects that had reached agreements with car companies and had or were about to set up refuelling pumps with E10 or E20 were withdrawn (Miljörapporten, 2000c). The reason for the ban on higher ethanol blends was resistance from the European car industry, which saw potential lower durability of older vehicles with high ethanol mixes and who doubted the

---

adjustment meant that the amount of tax for environmental vehicles was adjusted according to their conventional (fossil) counterpart (Statsrådsberedningen, 1999; Persson & Ringholm, 1999: 6).

[70] The fuel distribution companies OK and Q8 merged in 1999.

environmental gains of ethanol (Miljörapporten, 2000a). This indicates that the vehicle industry may not have been that hesitant about ethanol in Sweden, but was increasingly so in Europe.

However, despite the restriction of ethanol blends to 5%, the current limitation of alcohol mixes in gasoline meant that there was still room for expansion. Hence, as a result of the start of the Agroetanol plant in 2001, the agreement to distribute the fuel in a low blend in the Stockholm region resulted in a drastic market expansion (Energimagasinet, 1999; Karlsson & Jalmby, 2007)(see also

Table 30 below).

Eventually, following the EU announcement of a Biofuel directive setting implementation targets for biofuel, the government decided to exempt tax for ethanol trials as well. Late in 2002 it was decided to exempt large amounts of ethanol and Rapeseed Methyl Esters (RME) from energy and CO_2 taxes in 2003. The one-year ethanol tax exemption was given to five Swedish companies, one of which was the largest ethanol distributor SEKAB. Following this decision, OK/Q8 agreed a deal with SEKAB to enable a 5% mix in all its gasoline (Miljörapporten, 2003c). A month later, additional oil distribution companies such as Hydro, Jet, Preem, Shell and Statoil followed OK/Q8's example. In this way, the practice of mixing ethanol in gasoline, that had previously been limited to the Stockholm region, was spread across Sweden (Miljörapporten, 2003g). According to the statistics presented in

Table 30, the percentage of gasoline with E5 grew from 21% in 2002 to 85% in 2004. Post-2005, the percentage of gasoline with E5 was 92-95% (Statens energimyndighet, 2011).

The EU Biofuel directive was implemented in 2003, setting indicative market implementation targets of 2% biofuel by 2005 and 5.75% biofuel in 2010 (EC, 2003a). In addition, changes were made to the Mineral oil directive (EC, 2003b) to enable increasingly generous tax exemptions for biofuels. In line with the ambition of Swedish biofuel actors to implement more biofuels than the target set by the European Commission, Sweden set a biofuel implementation target of 3% for 2005 (Miljödepartementet, 2004; Persson & Messing, 2006). Following these changes, the Swedish government gave a general five-year tax exemption for all biofuels, starting in 2004, which all actors could apply for. Previously only predefined producers and importers could apply for the tax exemption (Persson & Ringholm, 2003).[71] This meant that oil companies and other actors were free to buy and import foreign ethanol instead of being restricted to the expensive Swedish ethanol market. This was perceived as a threat to Agroetanol, which had fuel contracts with fuel distributors ending in 2005 (Samuelsson, 2004i).

An additional policy instrument to reach the biofuel implementation target was introduced in 2005, making biofuel distribution facilities at filling stations mandatory. All filling stations selling more than 1 000 m^3/year, that is 2 600 of the 4 000 filling stations in Sweden, had to have at least one biofuel pump. The obligation, with which the largest fuel stations complied first, was implemented successively. Stations selling more than 3000m^3 fossil fuel per year were to comply by 1 April 2006, more than 2500m^3/year by March 2007, more than 2

[71] The Swedish ethanol producers were SEKAB, producing sulphite ethanol, and Agroetanol, producing grain ethanol. The main importers were SEKAB, Talloil AB and Romaetanol (Sandebring, 2004). The ethanol produced in Sweden in 2005 was produced at the Agroetanol plant and at Svensk Etanolkemi AB (SEKAB). The majority of the ethanol was used for low blends in gasoline, while about 15% was used in pure or almost pure (E85) form (Sandebring, 2004: 117).

000m^3 per year by March 2008 and more than 1000m^3 per year by March 2009 (Persson & Messing, 2006).[72]

Even before the law, in 2004 there were 120 pumps. BAFF had set a goal of 1 000 E85 pumps by 2008 (Samuelsson, 2004a). The increase in pumps is likely to be related to the earlier tax exemption and demand in relation to the new FFVs ordered. With the implementation of the law the number of pumps increased rapidly. By October 2007, the number of refuelling stations providing E85 had reached 1000 (SEKAB, 2011a), which meant that the goal set by BAFF had been reached earlier than expected. According to a study by the Swedish EPA (Björsell, 2004), one of the main reasons why oil companies were interested in the ethanol market was the profit they made. Imported ethanol from Brazil used for low blend ethanol gave a profit of SEK 500-700 million annually. This was due to the overcompensation by the tax exemptions in force for low blend ethanol, which were just right for E85 and too low for low blend RME (Björsell, 2004). A complementary factor for increased ethanol distribution was a recent increase in particular import practices that reduced the price of all types of ethanol fuel imports. According to Sandebring (2004), it had become increasingly common to import Brazilian ethanol under the nominator 'chemical product', which was not that strange considering that the chemical company SEKAB was the main ethanol importer. In this way, high tolls were avoided which were compulsory when importing the ethanol by the conventional agricultural routes.[73] In 2003, the import of ethanol from Europe and Brazil rose from only a minor share of the ethanol market to bigger than the share of the ethanol produced domestically (Sandebring, 2004). The increased use of imported ethanol, mainly from Brazil, was a trend that continued throughout this period (Bio-nett, 2009). The continued increase was probably also related to the demand for more ethanol use in order to reach the EU targets and the related benefits such as tax exemptions for ethanol fuel and ethanol lease cars.

Alongside the low blend ethanol, the ethanol FFV market continued to increase beyond the 8 000 vehicles running in 2003. This was partly a result of a second clean vehicle procurement organized by Clean Vehicles Stockholm in 2001. This time the focus was on gas and electric vehicles, but in the end the order also contained 6000 ethanol FFVs at the request of purchasers made up of a variety of public authorities and private companies all over the country. Three incentives supported the development of alternative vehicles, also known as 'clean' vehicles. First, in 2000, the Clean Vehicles Stockholm had arranged free parking for electric cars in Stockholm. A more general free parking rule covering all clean vehicles used by residents and for commercial purposes, and thus also FFVs, was applied in the period May 2005 to the end of 2008. To avoid abuse by non-environmental vehicles, the city issued permits. In addition, drivers of the clean vehicles had to be able to show receipts from filling stations to prove that the vehicle had predominantly been driving on renewable fuels. Second, Stockholm city implemented a congestion tax that exempted clean vehicles. The city of Stockholm and the government introduced the tax by means of a trial from January to July 2006, which continued after an evaluation and the institutionalization of the tax permanently in August 2007. All clean vehicles registered before 2009 were to be exempt until August 2012,

---

[72] To oblige fuel stations to provide biofuels was first articulated by the Social Democrats (in a minority government), the Left Party and the Green party in a government bill in 2002. Intense debate led to a renewed bill in 2005 (Skyldighet att tillhandahålla förnybara drivmedel (prop. 2005/06:16)) that restricted the fuel supply obligation to larger fuel stations in its initial stage and small stations in the future (see also Prop. 2005/06:160)

[73] This has been up for discussion at the EU. In 2009 it became clear that SEKAB would receive continuing low import tolls provided that the ethanol met the quality and sustainability standards set out by the EU (Häggqvist, 2009).

but newly registered clean vehicles after December 2008 no longer profited from the exemption. A third incentive was the clean vehicle premium – a SEK 10 000 rebate to private individuals who bought a clean vehicle. It was set for the period 2007 to 2009 to stimulate the growth of the clean vehicle market beyond fleet owners. The government had set aside SEK 815 million, of which 50 million was reserved for 2007, 340 million for 2008 and 425 million for 2009 (Birath & Pädam, 2010).[74] While the clean vehicle premium was national, two other large cities in Sweden, Malmö and Gothenburg, applied local incentives such as free parking in order to stimulate market expansion for clean vehicles. These support measures also benefited gas, hybrid electric and to some extent RME vehicles (Lindemalm, 2003). However, in this period Stockholm was leading ethanol FFV development.

Clean Vehicles Stockholm gained a variety of project funds from the EU Framework programme. Applications were not made in relation to existing EU programmes. Instead, Stockholm City took a leading role in defining areas for funding, gathering necessary partnerships to exchange lessons and secure funding. Trendsetter was one of the EU programmes that contributed funds for communication regarding environmental vehicles, which in turn contributed greatly to the market expansion. For instance, Trendsetter financed part of the web portal (www.miljofordon.se) that Clean Vehicles Stockholm, Gothenburg and Malmö set up to inform people about the various environmental vehicles available on the market. Other EU funds contributed to the 'one week free tests' of environmental vehicles for businesses and public authorities, to get them better acquainted with the technology before purchase. The EU programme with a direct aim to support the development of ethanol vehicles was the BioEthanol for Sustainable Transport (BEST) programme (Birath & Pädam, 2010). BEST ran between 2006 and 2009 and was coordinated by Stockholm city in collaboration with the Swedish BioFuel Region in Örnsköldsvik and international colleagues in Rotterdam, Madrid, La Spezia, the Basque Country, Somerset County, Nanyang and Sao Paolo. The aim of the BEST project was to explore infrastructure, and stimulate ethanol use in vehicles in the context of the EU's strategy to reduce consumption of fossil fuels and greenhouse gas emissions. Among other things, BEST contributed to experimentation with various ethanol fuels, demonstration of 77 000 FFVs and 190 ethanol buses, and the increase in low blends and related infrastructure of various ethanol fuel systems (BEST, 2010). Since Sweden was a forerunner, Swedish actors could not only further their own technology, but also share their experience and knowledge on ethanol development with countries interested in following the Swedish example. The project had a total budget for all partners of approximately SEK 185 million, of which the EU provided about SEK 82 million (Stockholms stad, 2010).

The ambition to expand the ethanol fleet to transport vehicles, mainly used by municipalities and small businesses, triggered the third ethanol-related vehicle procurement, but now with a focus on ethanol. The Environment and Health Administration of Stockholm city, which had main responsibility for the Clean Vehicles Stockholm project, led the procurement from 2005 to 2008. The City's own environmental investment programme, the 'Environmental Billion Fund', gave financial support to the procurement. The Administration of Stockholm city followed a similar process of dialogue with both buyers and producers as in the case of the FFV procurement, which resulted in the selection of a 2-3 m^3 VW Caddy, and

[74] Reduced vehicle tax for passenger cars complying with environmental requirements was introduced in 2006. The tax was based on the type of fuel used and CO_2 emissions. Carbon differentiated vehicle tax only applied to newer passenger cars. All other cars were taxed as before, based on weight and fuel type. In 2009, a new rule was introduced on tax exemption for new clean vehicles. As compensation for the early withdrawal of the clean vehicle premium, all purchasers of new clean vehicles would be exempt from vehicle tax for five years from 1 July 2009 (Birath & Pädam, 2010)

41 local public authorities and companies and 186 privately owned companies ordered the ethanol delivery van from VW. After a delay of almost one year with the first order, VW withdrew from the scheme as it could not manage to make the ethanol engine powerful enough for the delivery van. To compensate for this misfortune, they offered a discount on a biogas powered Caddy. However, this was only attractive to the actors that saw this as an useful alternative and had access to biogas (Birath & Pädam, 2010). Consequently, the ethanol market failed to expand to delivery vans.

Following the positive result of the organized procurements and the national and local authority incentives, an FFV market emerged which triggered interest in FFV development among domestic vehicle producers. According to media reports (Miljörapporten, 2001d), interest in developing FFVs among Swedish car manufacturers was already visible in 2001 (Miljörapporten, 2001d). However, according to Samuelsson (2004j), it was in 2004 that it became clear that both Volvo and Saab planned to make ethanol vehicles. Again it was pointed out that there were no technical problems for either Saab or Volvo to create an ethanol FFV, since both Ford (the owner of Volvo) and GM (the owner of Saab) already used flexi fuel technology. The main barrier was future market demand. In addition, Volvo feared that an ethanol FFV might compete with and potentially undermine Volvo's more expensive biogas vehicles or the Ford FFV (Samuelsson, 2004j)

Eventually, in September 2004 Saab announced the launch of its first environmental vehicle, a Saab 9-5 with an ethanol FFV turbo engine. The reason for developing an ethanol car, according to Åslund, information manager at Saab, was that Saab had 'to adjust to the environmental requirements of the public procurement' (Ringström, 2004, translation by the author). Hence, for Saab this was not only to find new customers, but also to keep old ones, since ever more public authorities demanded environmental leasing vehicles. They expected the car to enter the market in 2005. It was the first ethanol propelled car in the 'large-car-class', and which had Swedish white-collar workers as a customer group. The sales arguments from Saab were that the car would be sold at the same price as its fossil counterpart, that it had lower fringe benefit tax, lower fuel consumption at higher speeds, better performance and could be refuelled with gasoline if there was no access to ethanol (Ringström, 2004).

Following Saab's announcement, Volvo announced an ethanol car (Samuelsson, 2004k). According to Samuelsson (2004k), Volvo was forced to follow Saab's example to avoid losing market share. According to Anders Wahlén at Volvo, 'We hope that the investment in ethanol cars will stimulate the sales of our gas hybrid cars as well by increasing the focus on alternative vehicles. Ethanol is good in the short to medium term, but we see our gas propelled Bi-Fuel models as best for the long term if they are propelled with pure biogas' (Samuelsson, 2004k, translation by the author). The quote indicates the focus on gas vehicles at Volvo and that ethanol FFV is seen as a bridging technology only.

In 2005, both the Saab 9-5 (BioPower) and the two Volvo FFV versions of the S40 and V50 were introduced on the market as promised. While Ford was a forerunner, Saab's and Volvo's developments encouraged additional companies, such as Renault, Peugeot and Citroën, to announce plans to launch FFV models (Bio-nett, 2009).

According to an article in the journal Miljörapporten, the ethanol distribution and producing company SEKAB, the ethanol vehicle industry (Scania, Saab and Ford) and the Minister of Environment Carlstedt (Östling et al., 2006), argued that ethanol market expansion was threatened due to an increase in the ethanol price, which in 2006 passed the gasoline price. They suggested that the government should compensate for this price difference by means of two measures. First, the government should take away the VAT on all renewable fuels until 2010, particularly during times of increasing competition. Second, the government should support research and industrial development on ethanol production in order not to lose Sweden's head start in ethanol technology development and the potential social and economic benefits for the industry (Östling et al., 2006). The government did not take any extraordinary measures to follow up on these recommendations, but the vehicle statistics show a positive ethanol market trend.

According to the statistics (see Table 28), FFVs dominated the alternative light vehicles in this period. In 2002, FFVs had surpassed the number of registered gas cars as a result of the first common procurement process in 1998. Deliveries of first 5000 and later 6000 vehicles, and the entry of several new FFV vehicle brands on the market post-2005 are also possible to trace in the increasing market share shown in Table 28.

Light vehicle type	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Evs	600	-	500	450	400	360	320	310	280	157	191
Electric hybrids	250	350	530	620	1 350	3 300	6 100	9 400	13 500	14 165	16 802
Natural-/ biogas	1 500	1 640	2 500	3 440	4 500	6 600	10 500	12 900	15 000	16 946	25 314
Ethanol E85	250	890	3 500	7 980	13 300	21 400	46 700	81 300	138 000	173 122	200 252

Table 28: Light vehicles run on alternative fuels, 2000-2010
Source: for 2003-2008 www.miljofordon.se and for 2009-2010 (Pädam, Fenton, & Waluszewski, 2010)[75](Larsson & Karlsson, 2011)

In December 2007, the number of ethanol vehicles in Sweden reached 100 000 (Fock, 2007c) and more than 200 000 vehicles by 2010 (see Table 28). This development was much faster than expected, given that the ethanol proponent, Carstedt, in 2004 had announced a goal of 100 000 vehicles by 2008-2009 (Samuelsson, 2004h). In addition, the number of ethanol vehicles increased and the value of ethanol vehicles on the second-hand market was higher than that of gasoline vehicles (Fock, 2007c). This indicates high expectations regarding the future of ethanol FFVs, which may also be related to the fact that an ethanol vehicle owner gained many benefits compared to conventional vehicle owners. Carstedt (Fock, 2007c) argued that this remarkable implementation pace of ethanol vehicles made it likely that Sweden would reach the EU goal of 10% renewable transport fuels in 2020. From his perspective, ethanol was the only fuel that could supply the high volumes necessary to substitute for fossil fuels in the transport sector.

In contrast to the expansion of FFVs, the ethanol bus niche faced considerable challenges. One related to the emissions reductions of ethanol buses. In the late 1990s, a research report published by the Swedish Road Administration argued that ethanol buses used in Stockholm had very limited environmental benefits. The report stated that modern diesel buses with particle filters released the same amount of carbon hydrogen, particulates and CO_2 emissions as the ethanol buses in Stockholm. One reason for the relatively high emissions of the ethanol buses was the use of ethanol fuel based on Italian red wine (Miljörapporten, 1999c).

[75] This table covers registered vehicles only.

Another challenge for the bus niche was Scania's decision in 2003 to withdraw from ethanol bus production after more than 30 years in the business (Miljörapporten, 2003a; Karlsson & Jalmby, 2007). According to Urban Johansson at Scania, the reason for withdrawal was twofold. First, because ethanol fuel was more suitable as a blend fuel, particularly as a blend with gasoline as in the case of FFVs, compared to use in diesel engines as in the case of the Scania buses. Second, there was an increasing worry that there would not be sufficient feedstock to meet the increasing demand for ethanol (Samuelsson, 2005f).

For Stockholm, which had already replaced 250 of its diesel buses with ethanol buses from Scania, a new approach had to be sought to meet the city´s environmental ambitions. Biogas was promising, but a bottleneck was the limited biogas supply in the region, which would not be able to meet the demand in the long term (Miljörapporten, 2003a). Consequently, the local public transport company SL tried to get together a consortium of different companies that would be interested in buying ethanol buses (Lindemalm, 2004b).

However, in 2006 the wind changed at Scania. Stefan Petterson, future strategist at Scania, argued that the biggest potential for Scania in the short term was ethanol use. This was due to growing interest abroad, indicated by orders for Scania ethanol buses from Poland, Italy and Spain. According to Pettersson, ethanol production was expanding due to the increasing price of oil, which made ethanol a relatively cheap option (Samuelsson, 2006c).[76] However, Pettersson's prediction of cheap ethanol did not hold. In the very same year, ethanol proponents complained about the high price of ethanol in relation to gasoline (Östling et al., 2006). Despite this, SL's order of 85 new ethanol buses from Scania in 2009 indicated that the collaboration between SL and Scania was back on track (Dahlquist, 2009).

In the case of the ethanol cluster Biofuel Region in the north of Sweden, coordinated by BAFF, Scania´s temporary production stop and withdrawal from the project led to severe cutbacks in the ethanol bus fleets of the local municipalities. In the late 1990s, the regional fleet was still expanding with additional buses in Sundsvall and Umeå. However, due to Scania's decision, Sundsvall municipality decided to terminate its effort and Umeå reduced its fleet from 35 buses to 20. Only the fleet of 15 vehicles in Örsköldsvik remained intact despite this incident (Karlsson & Jalmby, 2007). With the exception of the withdrawal of Scania, which had damaged the credibility of ethanol in selected cities, Karlsson and Jalmby (2007) argue that the development of ethanol buses in the Biofuel Region had been positive. The removal of technology bottlenecks meant that the cost of reducing CO_2, NO_x and particles using ethanol bus technology had become negligible.

Alongside the development of pure ethanol fuel use, new field trials emerged of low blend ethanol in diesel. According to Löfvenberg (2007), these trials started in the second half of the 2000s. There were also various lab experiments with either low blend ethanol in diesel, called Diesohol, or the use of ethanol derivates in diesel, so-called ED-diesel. ED-diesel was considered particularly promising and it was concluded that a 10% mix of the ethanol derivate in diesel was ideal in order not to lose engine power and to fit the fire standards. The first emission study was a bench test in 2003 carried out by SEKAB at STT Emtec's engine test centre in Sundsvall. SEKAB's test delivered very positive results, showing a reduction of particles by 21%, CO by 17%, NO_x by 2% and CO_2 by 8%. Due to a decline in energy density, fuel consumption increased by 2.8% (Löfvenberg, 2007).

In 2006, preparations began for a demonstration with ED-diesel. A number of fleet-owners showed an interest. At the end of 2006, SEKAB signed a contract with the public transport company Veolia AB in Örnsköldsvik. SEKAB assigned two Scania buses for the trial,

[76] A second option is biogas. With regard to the long-term perspective, Scania is investing in hybrid electric buses (Samuelsson, 2006c).

operating in regular public transport in Örnsköldsvik. While Veolia already had infrastructure for fuelling their buses with diesel or ethanol, this technology required a new fuel pump and a separate tank. SEKAB imported the ethanol derivate from China. The fuel distribution company Preem delivered the diesel, which contained 5% RME as well as 10% ethanol. Consequently, the ED-diesel used in the trial contained 15% biofuels. The trial started in May 2007. After six months, there had been no operational problems. A bench test showed a decline in engine power of 3.6%, which was expected based on the reduced energy density of the fuel. However, some of the drivers argued that the power was the same as that of fossil diesel vehicles or even better. The only problem in the trial was complaints from drivers and some passengers about the smell, which is similar to that of ether. The ether smell can be very irritating and was particularly disturbing during refuelling and at bus stops. In late 2007, there was still no solution to this problem, but closer evaluation of the problem was planned at the end of the project in 2008 (Löfvenberg, 2007).

Heavy vehicles	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Etanol*	400	380	370	490	490	510	553	619
Natural-/biogas	680	780	900	1 120	1 160	1 300	3 820	3 977
Electric and fuel cell	17	18	13	9	10	10	155	34

Table 29: Heavy alternative fuel vehicles, 2003-2010

Source: for 2003-2008 www.miljofordon.se and for 2009-2010 (Pädam et al., 2010)[77] (Larsson & Karlsson, 2011)

*2003-2008 concerns ethanol buses alone

The challenges for the ethanol bus fleet, in particular the temporary withdrawal of Scania from the ethanol bus cluster, is likely to explain part of the decline in 2003-2005 shown in Table 29. An increase in buses is visible in 2006, although there is no indication that these were buses were delivered by Scania. Overall, the development of heavy ethanol vehicles was weak compared to the successful development of heavy gas vehicles. However, both ethanol and gas vehicles were successful in comparison with electric and fuel cell vehicles, which were few and declining in number during this period.

In the mid-2000s, there were high hopes of expanding the EU mineral oil standard that limited the ethanol blend in gasoline to a maximum of 5%. According to Samuelsson (2006a), it seemed as if the previous resistance from the European automobile industry and member states had gone. He reported that the European automobile industry had become increasingly positive about low blend biofuels. This was because low blend biofuels increased their ability to reach the new CO_2 reduction targets set by the European agreement, Acea. In addition, member states were increasingly positive since the plans to make the Biofuel directive targets obligatory made a higher ethanol mix a way to reach the implementation target.

Expectations of permission to mix up to 10% ethanol in gasoline, as well as the expectation of an expanding FFV market, led the farmers' organization Lantmännen to make plans for the construction of another grain ethanol plant (Samuelsson, 2006b; Miljöfordon, 2006). In addition to the economic gains for agriculture, Lantmännen argued that it would contribute to a reduction in oil dependency and greenhouse gases. The plant would benefit the agricultural sector by creating a market for the current Swedish grain surplus, which was the designated feedstock. The new plant would produce four times more than current ethanol

77 This table covers registered vehicles only. Number of vehicles for earlier years has not been reported.

production from Agroetanol. Lantmännen planned to locate the plant next to the old plant in Norrköping and expected it to be ready for production in 2008. Lantmännen's investment in the plant was SEK 1 billion. No other investors or funds were reported (Miljöfordon, 2006), although Lantmännen was likely to have benefitted from the tax exemption on ethanol.

Fuel type	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Low blend	-	-	0	24	58	125	235	252	248	244	228	229	216
Other	-	-	26	18	18	25	25	33	72	114	194	160	184
Total	14	16	26	42	76	150	261	285	321	358	422	389	400

Table 30: Ethanol consumption expressed in 1000m^3, low blend and other (e.g. E85-E95), 1998-2010
Source: 1998-1999 Sandebring (2004), 2000-2010 Statistics Sweden.

In 2007 it became clear that Agroetanol's ethanol production was in serious trouble due to rising grain prices, which resulted in a brief halt in production in the spring of 2007 (Samuelsson, 2007d). Despite this, the new plant was ready to start production in November 2008. Hence, with the new plant the total capacity of Agroetanol increased to about 210 000m^3 ethanol and 175 000 tonnes of feed. The total feedstock input was 550 000 tonnes of grain. Ethanol production was still focusing on feeding the low blend market, but a limited amount went to high blend use in buses. The new plant was highly energy efficient due to the use of steam from an energy production plant nearby, which made it part of a so-called biorefinery process (Lantmännen, 2011).

Looking at the overall distribution of ethanol, the largest part of ethanol use went to the low blend ethanol market to which the Agroetanol plant was the main contributor. Since 2004 the use of low blend ethanol has been constant due to a close to 5% blend in all gasoline distributed (Statens energimyndighet, 2011). Hence, the slight fluctuations in

Table 30 relate to the fluctuations in gasoline used. The reduction in pure or high blend ethanol was a trend break caused by increased use of gasoline in FFVs as a result of a higher ethanol price in 2009 (Statens energimyndighet, 2011).

Advanced cellulose ethanol

Alongside conventional ethanol production and use, ethanol actors continued to develop advanced cellulose ethanol production technology. Despite the shortfalls in the Ethanol Development Programme in the early 1990s, the cellulose ethanol research programme was prolonged by another seven years in 1998 (Persson & Sundström, 1997; Persson & Uusman, 1998). The second term of the cellulose ethanol research programme was called the Programme for Ethanol from Forest Feedstock. The programme aim was to demonstrate ethanol production in large-scale plant and to lower the costs for the production of cellulose ethanol. The programme funds were set at SEK 30 million annually or 210 million in total for the period 1998-2004, which was a doubling of the programme funding compared to the previous period.[78] The programme was one of the main R&D investments in the 1997 government bill. The total cost of the programme was SEK 217 million, of which the additional SEK 7 million was acquired outside the programme budget (Vallander, Östman, & Wimmerstedt, 2006).

Government financing of the ethanol programme is likely to have been related to the many actors supporting cellulose ethanol and willing to take on the construction of a cellulose ethanol plant before the start of the programme. The network behind the development of the ethanol cellulose plant in Örsköldsvik was made up of a variety of municipalities in the region as well as a working group of actors representing mainly the large energy companies in the county of Norrland and the organization SSEU, later known as BAFF. These actors formed the Energy Centre Norrland (Energicentrum Norr, ECN)[79] and asked for funds from the energy authorities. The ECN applied for additional funds from the various county administrative boards in the Norrland region, from the energy companies in Norrland and from the regional funds provided by the European Union. While other local authorities sent in applications to finance a cellulose ethanol plant, the government awarded it to ECN in Örsköldsvik in 1998. The choice of ECN was motivated by the abundant forest residues in the region that could be exploited for ethanol production, the ongoing ethanol production by Domsjö fabriker AB, the great ethanol-related know-how of SEKAB, and the

[78] For the previous period a budget of 45 million SEK was available for developing new technology for ethanol production in the three-year period 1993-94 to 1995-96.

[79] ECN later became known as Etek Etanolteknik AB and is currently part of SEKAB (Fallde et al., 2007).

strong economic motive to keep ethanol production in the region (Fallde et al., 2007). The promise of ethanol, however, was not restricted to regional growth in the region. Per Carstedt, chair of BAFF, also expressed the potential of ethanol as a long-term solution for the transport sector. He pointed out that there was 600 000 hectares of unexploited cultivation area for energy forest, which could make Sweden self-sustaining in ethanol (Miljörapporten, 2003b).

The ethanol R&D programme started in May 1998. In mid-2000, ECN delivered a pre-projection of the pilot plant and a study for a future demonstration plant. The ECN plan was that the plant would be set up at the site of the ethanol chemical company SEKAB in Domsjö outside Örsköldsvik. ECN preferred weak acid hydrolyses technology, which breaks down the cellulose with sulphuric acid at high temperature (about 200 °C.). However, contemporary research in Sweden was focused on enzymatic hydrolyses. Based on a cost-benefit analysis, the Energy Authority decided to finance a pilot plant including both the weak acid and the enzymatic hydrolyses technologies. The construction was quite expensive compared to other alternatives, but it was considered cheaper in the long run than having to reconstruct the plant to enable the use of the enzymatic processes. The total investment budget was SEK 148.4 million, of which the main proponent, the Energy Authority (and thus the Ethanol programme), contributed 75% or SEK 112.4 million (Vallander et al., 2006). The ownership of the project was divided between three universities: Umeå University, Lund Technical University and Mid Sweden University College (Miljörapporten, 2001b). Construction began at the end of 2001 (Fallde et al., 2007).

To manage the further development of cellulose ethanol, a non-profit organization – the BioFuel Region (BFR) – was set up in 2003. It was supported by the three universities running the project, 15 municipalities in the counties of Västernorrland and Västerbotten, but also counties, national government agencies (Swedish Road Administration and Nutek) and some regional businesses. The BFR gained funding through Vinnväxt, a development programme for regional innovation and growth set up in 2001 by the Swedish Agency of Innovation Systems (VINNOVA), in 2002. In addition to ethanol, the promise of fuels based on syngas, especially Fischer-Tropsch diesel, appeared on the agenda. While interest in FT-diesel was growing, regional actors considered ethanol the number one fuel (Christensen, 2005). According to the BFR vision set out in 2003, the local ethanol industry would make the county of Västernorrland in the north-west of Sweden independent of fuel imports by 2030 at the latest. In addition, heat and energy would be produced based on waste from the ethanol production process. Jan Lindstedt, one of the managers of BFR, hoped for large scale ethanol production by 2008 and researchers like Zacchi from Lund Technical University claimed this as technically possible (Miljörapporten, 2003h). In addition to these contributions at the regional level, the project's ambition was to offer a world-leading model for converting to a sustainable transport system (Christensen, 2005: 36). The means to achieve the vision involved not only lobbying for biofuel-related R&D funds and initiatives at the university and industry levels, but also gathering more actors to the BFR network to set up public stimuli, such as free parking for biofuel cars and, finally, public educative programmes about the technology. BAFF, which took a more central organizational position in the BFR at a later stage, had initial problems accepting FT-diesel but became more lenient over time (Christensen, 2005).

The project team inaugurated the pilot plant in 2004. The aim of the pilot was to start with the development of the weak acid hydrolysis, followed by a series of enzymatic hydrolysis tests in 2007-2008. After developments in the many process steps at the pilot plant, it produced the first cellulose-based ethanol in 2005. Meanwhile, the ethanol programme funded preparatory laboratory scale experiments with enzymatic hydrolysis at Lund Technical University together with 50 additional projects geared to lowering the production cost of wood-based ethanol. These initial experiments showed progress with regard to the production costs, which were about SEK 3-5 /litre, the production process and its efficiency. Also at the site of the pilot plant, the trials with weak acid hydrolysis were successively finalized and the enzymatic experimentation was started. The project team planned the second step, to scale-up the pilot to a demonstration plant based on biorefinery technology. Carstedt hoped for construction of the demonstration plant by 2007. The final step was to apply either the weak acid or the enzyme technology in a large scale commercial biorefinery plant connected to one of the many heat production plants in the region. Expectations were high. According to Carstedt, all doors were open: 'The world is on a pilgrimage to Örnsköldsvik, we are regarded as world leading in ethanol production from cellulose' (in Westergård, 2006c, translated by the author). Part of the vision was the creation of 20 000 high quality jobs. Nevertheless, to realize the large international biorefinery plant envisaged, government support of SEK 100 million annually was still needed (Westergård, 2006c). Meanwhile, cellulose ethanol proponents continued to support conventional ethanol development: 'We should be world leading in cellulose ethanol. But while waiting until we can start delivering, we have to rely on ethanol from grain and sugar cane' (Carstedt in Westergård, 2006c, translated by the author).

When the second phase of the Ethanol Programme ended in 2004, the government awarded no follow-up funding. Consequently, the BFR, SEKAB and the researchers at Lund teamed up to lobby for funds and prepare a plan for a new ethanol programme (Falk, 2006). In January 2007, the Energy Authority prolonged the Ethanol R&D Programme for a third time. SEK 144 million was given to keep the programme running until the end of 2010. The aim of the programme was to build an enzymatic ethanol demonstration plant by 2010. The long-term ambition was to produce cellulose ethanol to successively substitute for fossil fuels in the transport sector and reduce dependency on oil producing countries (Energimagasinet, 2007).

Nonetheless, the project suffered heavy delays. Carstedt announced that a factory in Örnsköldsvik could not be built before 2010. As a result, SEKAB put the up-scaling of the ethanol plant on hold. Instead, SEKAB invested USD 600 million in sugar cane ethanol production in Mozambique and Tanzania. According to Eva Fridman, CEO of BFR, the problems setting up a plant in Sweden were due to the scarcity of woody raw material, a result of competition with other industries (Fock, 2007d). While competition from a variety of industries using waste wood, such as the furniture, and paper and pulp industries, was predicted in 2003, estimates had not predicted the vast increase in competition for waste wood due to the growth of the bio-based energy and heat sector (Miljörapporten, 2003d; Fock, 2007d). Despite its investment in sugar cane ethanol, Friedman argued that SEKAB's cellulose ethanol project would continue, and that the conventional ethanol plants abroad were just a means to meet market demand (Fock, 2007d). However, as is indicated in

Table 30, ethanol sales were heavily reduced in 2009 due to increasing ethanol prices. In addition, environmental organizations and NGOs criticized SEKAB's ethanol production project in Africa for causing negative environmental and social impacts. Consequently, SEKAB decided to close all its foreign projects in February 2009 (Benjaminsen et al., 2009). During this time, Sekab and Luleå and Umeå Universities continued to carry out R&D activities at the domestic cellulose ethanol demonstration plant. However, the economic situation of the project became drastically weaker and Sekab cancelled the operations agreement in late 2011. In 2012, Alpman (2012) reported that the pilot was 20 million in debt and threatened with closure. Due to EU regulations on government support, the universities are not allowed to buy the plant. The closure of the plant would mean that Swedish scientists and industry would have to depend on foreign operation units to further cellulose technology (Alpman, 2012).

8.1.2. Ethanol SNM analysis, 1998-2010

Ethanol														
Year	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Network	SSEU		BAFF											
	Clean vehicles Stockholm													
							BFR							
Field trials	**E10 OK/Q8 distribution**													
					E5 other oil companies follow.									
	ca 30 E85 pumps						**95**	**120**			**1000**			
	Sulfate ethanol + import							expansion						
					Plant Agroetanol							2plants		
FFVs				250	890	3500	7980	13300	21400	46700	81300	138000	177524	206879
									Private market, additional brands					
Buses	300						400	380	370	490	490	510	553	619
R&D fuel		R&D program									R&D program			
								Pilot plant						

Table 31: Ethanol development, 1997-2010

Conventional ethanol

Network actors	Biofuel	Expectations	Key experiments	Learning	Socio-technical configurations
Farmers' cooperatives, chemical industry and sulphate ethanol producer (SEKAB), municipalities (of which many collaborated in SSEU), oil distribution companies and (domestic) vehicle producers except SCANIA which withdrew temporarily. Clean vehicles Stockholm takes a leading role. Great expansion and continued high level of alignment.	Ethanol pure and low blend use, production	Similar expectations as in previous period with ethanol as best biofuel alternative in terms of costs and emission reduction, and conventional ethanol as a bridging technology to advanced ethanol. Expected market expansion as a result of EU policy.	Despite limiting EU standards, low blend use expands greatly. Expansion of FFV leasing fleets to private market. Wheat ethanol production starts again. However, domestic production increase is limited compared to the dramatic increase in imports to feed market expansion.	Successful market expansion and financial incentives go hand in hand. However, positive ethanol expectations reduced at end of period due to high feedstock price. This contributes to slow down in niche expansion.	Realization of bus, FFV and low blend market niches. Related infrastructure for distribution, storage in place as well as standards which indicate niche stability. Niche still dependent on imports, domestic production very limited.

Cellulose ethanol

Network actors	Biofuel	Expectations	Key experiments	Learning	Socio-technical confi-gurations
Universities, scientists, SSEU	Cellulose ethanol production	Cellulose ethanol to become a cheaper and more environmentally friendly fuel alternative. These expectations are severely reduced at the end of the period.	Cellulose ethanol pilot realized in 2004. Cellulose ethanol development slows down at the end of the period.	Despite the realization of a pilot plant, severe technical bottlenecks. Both technical and economic lessons contributed to reduced financial support for cellulose ethanol. Expectations once again proved unrealistic.	Remain R&D niche.

In this period, the central *actors* from the previous period, the farmers' organizations driven by crop ethanol production interests, the chemical industry, such as SEKAB, several municipalities and researchers collaborating within SSEU/BAFF, driven by cellulose ethanol production interests, were still joining forces to create a conventional ethanol market with Saab-SCANIA, Ford and OK. In fact, OK reintroduced low blend ethanol in 1997, which attracted additional oil distribution companies in the 2000s. Moreover, the farmers' organizations took a more active role and realized a crop ethanol plant in 2001. Finally, Stockholm city led the expansion of the FFV market in collaboration with municipalities and oil distribution companies. Financial support was gained by national and local authorities. However, development was hampered by restricted government tax exemptions between 1997 and 2004 and the limitation on ethanol blends by the EU to E5 in 2001. From 2004, however, actors providing ethanol vehicles, and importing and producing ethanol expanded their activities in tandem with increasing government tax exemptions and other incentives. One exception was SCANIA, which temporarily left the network in the late 2000s. Not only the growing ethanol network, but also its activities aligned with the expansion of the ethanol market were positive for niche development.

With regard to cellulose ethanol, the network remained more or less the same, with SSEU/BAFF and researchers at universities as the key actors who realized a pilot plant in 2004. However, unlike conventional ethanol production and use, the network had no financial hurdles in the early 2000s but funding was more limited towards the end of the 2000s, which led to network decline.

Continuously positive ethanol expectations, which were very similar to those of the previous period, stimulated niche development. A similar expectation to the previous period was that crop ethanol was the best currently available alternative fuel in terms of costs and emission reductions, which could be complemented by a more efficient and advanced ethanol alternative once it matured. A new element of the ethanol promise was that, compared to other biofuels, it was the only solution providing sufficient feedstock since there were sufficient waste crops and wood to meet demand. Despite the limited tax exemptions in the early 2000s, expectations remained high. This was partly due to the promise of an upcoming EU policy setting obligatory targets for biofuel implementation, as well as successful ethanol experiments and positive lessons. This relates to low blend ethanol as well as the improvement of FFVs. Learning on FFVs in particular indicated ambitions of user involvement and linkages of a variety of lessons, which turned out to be beneficial for niche development. However, in the last few years high ethanol prices caused a pause in domestic ethanol production and reduced use of ethanol in FFVs, which is likely to influence positive ethanol expectations in the long term.

Unlike crop ethanol, cellulose ethanol did not show an equally positive expectation and learning pattern. Despite the realization of a pilot plant, the expectation that cellulose ethanol would soon become a cheaper and more environmentally friendly alternative was once again proved unrealistic, and was less easy to adjust to. These techno-economic lessons contributed to reduced financial support for cellulose ethanol.

The decline in positive cellulose ethanol expectations, together with the increased costs of conventional ethanol, contributed to a slowdown in ethanol development in the last years of this period. Nonetheless, ethanol was still the leading biofuel alternative. This period resulted in a private FFV market niche in addition to the existing bus market niche, a great expansion in low blend ethanol use, and the realization of a crop ethanol production plant and a cellulose ethanol pilot plant.

8.1.3. Ethanol discourse development, 1998-2010

Following the developments in the previous period, the environmental discourse promoting CO_2 reduction increased in strength. This was shown in the stated aim in 1996 of the newly elected Prime Minister, Göran Persson, to make Sweden an international leader in the development of an environmentally sustainable society. Persson's green ambition led to the formation of a Delegation for Ecological Sustainable Development,[80] made up of cabinet ministers. One of the tasks of the delegation was to agree an environmental technology stimulation programme, which became known as the Local Investment Programme (LIP) (Riksdagens Revisorer, 1999). The LIP programme was not only a response to growing climate concern, it was also the result of a growing concern about the lack of employment opportunities in the countryside. As framed by the Environmental Protection Agency, the aim of the LIP was 'To significantly speed up the transition of Sweden to an ecologically sustainable society. A subordinate purpose was to help raise employment levels' (Naturvårdsverket, 2011a, translation by the author). Moreover, the LIP programme differed from traditional funding programmes focused on specific technology solutions. It focused on the achieving sustainability and increased employment by taking a bottom-up approach (ibid.). The bottom-up approach meant that only municipalities, in collaboration with other actors providing matching funds, could propose measures in line with the goals of the programme and apply for funding. LIP funds were granted to various projects in the period 1998-2002, although the last project funded was implemented as late as 2007 (Rehnlund et al., 2004; Naturvårdsverket, 2011a). The LIP programme mainly granted subsidies to biogas vehicles. Ethanol vehicles were the second-most funded. In addition, LIP supported the setting up of refuelling stations and production plants, which were mainly for biogas as well (Rehnlund et al., 2004). The amount of funding for biogas indicates that municipal actors supported the biogas discourse more than the ethanol discourse. The better fit of biogas with municipal interests in comparison to ethanol, linked to municipal responsibilities for waste management, emissions reduction and employment, can explain this. Nonetheless, that ethanol projects gained LIP funding indicates a certain positive connection between the ethanol and regional development discourses.

In 1997, the government stopped granting new tax exemptions (Riksrevisionen, 2011). Instead, the government budget bill for 1998 promised a general tax exemption for ethanol and other biofuels, despite the fact that current EU law did not allow it (Persson & Åsbrink, 1997: 173-174). The wish to continue tax exemptions for ethanol was also expressed in the negotiation between the Swedish government and the EU, resulting in an agreement that Sweden could grant a five-year tax exemption for ethanol (Kristenson, 1997b). As is outlined in the section above, the promise of a general biofuel tax exemption was mainly a result of pressure from a strong ethanol discourse increasingly embedded in a growing environmental discourse, the regional development discourse and to a certain extent the self-sufficiency discourse that had re-emerged because of the Gulf War.

In reaction to promised funding in the budget bill for 1998, various lobby actors came forward. One example is the increased lobbying for tax exemptions to support a crop ethanol plant by political parties other than the Centre Party, as outlined above. In addition, Miljörapporten (1999b) reported that oil distribution companies joined the lobby for tax exemptions once they developed an interest in importing ethanol in order to use it as a small scale blend in gasoline. The promise of the budget proposition for 1998 was repeated in both the Environment bill (Peterson & Lindh, 1998: 261) and the Transport policy bill (Persson &

[80] In Swedish: Delegationen för en ekologiskt hållbar utveckling.

Uusman, 1998: 152). Even though parliament passed accepted both bills, however, the government decided to withdraw them in 1999. The government granted a five-year tax exemption for only one grain ethanol plant (Agroethanol) while the rest of the applications were rejected. The reason for this change in policy, according to the Ministry of Finance, was great uncertainty over the environmental benefits of biofuels. The ministry referred to recent scientific reports that showed poor environmental gains from RME and ethanol (Miljörapporten, 1999b; Miljörapporten, 1999d). Given that the current exemption from both the energy and the CO_2 tax for biofuels equalled an annual tax loss of about SEK 80 million (Riksrevisionen, 2011), the hesitancy of the Ministry of Finance was not that surprising.

Unlike the crop ethanol discourse, the SSEU-based cellulose ethanol discourse increased in stability in the late 1990s. This was supported by the setting up of a seven-year R&D programme for cellulose ethanol in 1998, based on the belief that cellulose ethanol would be able to provide the most cost-efficient CO_2 reduction in the long term (Persson & Sundström, 1997; Vallander et al., 2006). Moreover, due to strong lobbying for a cellulose ethanol plant, initially by SSEU and later by a more dedicated lobby group of several municipalities and energy companies in the wider region of Norrland under the name Energy Centre North (ECN), the government granted funds to ECN for setting up a feasibility and project plan of the ethanol plant in 1998 (Vallander et al., 2006). According to a spokesperson at the Swedish Energy Authority, the main reason for this choice was the strong regional and municipal forces behind the ethanol project. Additional arguments were the availability of local resources of feedstock and knowhow as well as the expected contribution to regional employment and development (Tegner in Fallde et al., 2007: 72). Hence, in the case of the cellulose ethanol discourse arguments also related to the environmental discourse and the increased focus on CO_2 reduction as well as the regional development discourse, which increased in strength in the late 1990s and thereafter. This was also shown when Per Carstedt, chair of SSEU,[81] argued that 'the ethanol industry can create thousands of job openings and can be the solution for the transport sector in the long term'. Furthermore, Carstedt pointed out that there was 600 000 hectares of unexploited cultivable land for energy forest, and that: 'If this potential were to be exploited, Sweden would be self-sufficient in ethanol' (Miljörapporten, 2003b, translation by the author). This indicates not only the strength of the regional development discourse in this period, but also its close relation with the farmer livelihood discourse.

After negotiations, a very expensive and technology intensive ethanol pilot plant was chosen, with the expectation that it would become cost-efficient in the long term. Since the Energy Authority (Energimyndigheten) was a proponent of this solution, it offered to finance 75% of the research pilot plant. Because of this decision, construction started at the end 2001 (Fallde et al., 2007). Moreover, the linkages between the cellulose ethanol discourse and the expanding regional development discourse seem to have paid off. According to Christensen (2005), the non-profit organization, the BioFuel Region, which was initiated in 2002, gave additional support to the cellulose ethanol project from 2003 onwards. The aim of the BFR was to foster innovation and regional development with a focus on biofuels, particularly the development of cellulose ethanol and FT-diesel. The BFR was a broad collaboration of actors that, like ECN, included northern municipalities and county administrative boards, but also one government and one university. The collaboration was set up to gain funds from the Swedish Governmental Agency for Innovation Systems (VINNOVA) and their programme Vinnväxt, focused on creating regional innovation and

[81] At this point SSEU had changed its name to the Bio Alcohol Fuel Foundation (BAFF). The reasons for this name change are explained below.

growth. However, the BFR only gained limited funding. Instead, various members of the BFR as well as national actors, such as the Swedish Road Administration, contributed financial support for coordinating activities, information exchange and other activities. However, the focus was still regional development and collaboration, as outlined by VINNOVA. VINNOVA was set up in 2001 as a result of a number of government bills in the late 1990s. These bills addressed the increasing problem of migrating companies and labour opportunities, and thus also the migration of people from the Swedish countryside, which had created a negative development spiral that the VINNOVA was intended to turn around (Christensen, 2005). Hence, not only the LIP programme, but also the BFR could be seen as a product of the growing regional development discourse as well as the successful embedding of ethanol in this dominant discourse.

Although the Ministry of Finance reversed the previous promise of a general biofuel tax exemption and denied the great majority of applications in 1999, the ethanol coalition did not give up. This was partly due to the order for 3000 FFVs from Ford by Stockholm City and its partners in the same year. With the ambition to meet the expected ethanol demand, ethanol producers and importers lobbied even harder to get a tax exemption (Miljörapporten, 1999e). Due to the similar conditions for RME producers, these coalitions started to collaborate in lobbying for tax exemptions at the Ministry of Finance (Miljörapporten, 2000d).

The cellulose ethanol coalition also joined the lobby. For example, Per Nordgren from the ethanol production and import company SEKAB, argued that 'the moves of the Ministry of Finance gives strange signals, for example when thinking of the great investments made in ethanol propelled vehicles [FFVs]' (Miljörapporten, 2000b, translation by the author). Per Carstedt from BAFF and Claes Pile from the environmental organization the Swedish Society for Nature Conservation (SSNC) expressed similar thoughts about the Ministry of Finance in relation to the FFV project. An additional paradoxical policy decision highlighted by Carstedt and Pile was the implementation of a fringe benefit tax for environmental leasing vehicles from 2000 onwards. Without a tax exemption to reduce ethanol fuel costs, the FFVs would be run on gasoline, which would make the fringe benefit tax a useless stimulus (Miljörapporten, 2001e).[82] Given the intention of the cellulose ethanol coalition to create an ethanol market in order to create demand for cellulose ethanol fuels, as outlined in the previous section, its criticism of the halt in tax exemptions was not that surprising. The support for an ethanol market by the cellulose ethanol coalition is likely to have increased given that support had been gained for a plant and commercialization of the fuel was thought to be close. According to Professor Zacchi at Lund University (Miljörapporten, 2000e), the lack of an ethanol market stimulation by the government would undermine further support for developing cellulose ethanol technology to commercial production (Miljörapporten, 2000e). This indicates that the argument used in the 1980s, that crop-based ethanol was necessary as a stepping-stone for more advanced cellulose ethanol returned in this period.

Alongside the reappearance of the ethanol bridging technology argument and collaboration across biofuel coalitions to put pressure on the government to exempt tax on biofuels, new and broader bridging arguments appeared which indicate even wider collaboration. This development can be exemplified by the politician Peter Larson from the

[82] Environmental vehicles were more expensive than conventional vehicles. Hence, the government stimulated environmental vehicles by lowering their fringe benefit tax in 2000 to make them as cheap as their conventional vehicle counterparts (Statsrådsberedningen, 1999; Persson & Ringholm, 1999). Additional tax relief was given to gas and ethanol vehicles, which in the period 2002-2006 had only to pay 80% of the amount of their fossil fuel counterparts (Persson & Nuder, 2005).

region of Stockholm, who in reaction to the criticism of low emission reductions by ethanol buses argued that 'without the investment in ethanol we would not have had the development and use of cleaner diesel and gas propellants' (Miljörapporten, 1999c, translation by the author). Another example was Per Nordgren at SEKAB and Anders Forsman from the ethanol company, Roma Etanolproduktion, who argued that 'Lack of tax exemptions for ethanol can eliminate the investments that have been made in the past 15 years in Sweden; including the construction of infrastructure fit for hybrid cars and fuel cells' (Miljörapporten, 2000b, translation by the author). In addition, representatives from Statoil, Shell and the RME companies, Aspen Petrolium and Fred Holmberg & Co.. agreed with the basic assumption that tax exemptions for conventional biofuels were a prerequisite for the continued development of alternative fuels (Miljörapporten, 2000b).

The collaboration between various biofuel actors indicates that a broader biofuel coalition and discourse was emerging arguing that support for conventional biofuels was necessary for the development of more advanced and environmentally benign biofuel options, but also cleaner diesels and hydrogen. Five years later, Sandebring (Sandebring, 2004) expressed this even more clearly in a Commission report for the Investigation of Renewable Vehicle Fuels. He introduced the terminology of first-, second- and even third-generation fuels into the Swedish policy arena, to argue for a stepping stone implementation of biofuel technology. First-generation fuels referred to conventional agricultural crop-based fuels, second generation referred to advanced and cellulose based fuels and third-generation fuels referred to hydrogen or more advanced fuels. The broadening biofuel agenda was also picked up by the Centre Party, one of the most powerful lobby actors for grain ethanol, which decided to change its one-sided support for ethanol to support all alternative fuels. This was reflected in the statement by Centre party leader Maud Olofsson in February 2005: 'The Centre Party does not advocate one fuel over the other, even if I drive an ethanol car myself'. (Samuelsson, 2005a, translation by the author).

In addition to the coalition building that the cellulose ethanol coalition carried out with first-generation actors, it also tried to link up with methanol in a similar way to the alcohol discourse in the 1980s. It was the returning interest in methanol both nationally and internationally in the late 1990s that triggered the Foundation for Swedish Ethanol Development (Stiftelsen Svensk Etanolutveckling, SSEU) to change its name to the Bio Alcohol Fuel Foundation (BAFF) in 1999 (Christensen, 2005). However, while the ethanol actors indicated that they were willing to collaborate, the methanol and upcoming synthetic gasification coalitions were not as interested. Instead, they lobbied against further ethanol support, particularly for conventional crop-based ethanol (Miljörapporten, 1998c; Miljörapporten, 1998a; Hådell, 2001). This continued throughout the 2000s, as is described in the section on synthetic fuels below.

To enable the continued biofuel tax exemption, collaborations were also sought at the governmental level. While the Ministry of Finance held firm against further tax exemptions on biofuels, the Ministry of the Environment, which was pro tax exemptions, had gained an ally – the Energy Authority. In an evaluation of the use of the pilot project tax exemptions published in the summer of 2000, the Energy Authority argued that the continued production of biofuels, as well as the development of vehicles propelled by biofuels, needed an exemption from the CO_2 and energy taxes. In addition, it argued that the substitution of fossil fuels with biofuels was a powerful means to reduce CO_2 as well as other emissions dangerous for human health. Finally, it stated that the loss of tax income from exempting ethanol and RME from tax was much less than estimated by the Ministry of Finance (Miljörapporten, 2000d).

To avoid a steep increase in the price of alternative fuels, the Ministry of Finance eventually agreed to grant a one-year tax exemption for selected biofuels in 2002. Ethanol was not one of the biofuels that gained an exemption. Agneta Bergquist at the Ministry of Finance explained this by stating that: 'Old known ethanol technology will not be included in the much disputed pilot project exemptions. We will not hold the ethanol industry under their arms [...]' (Miljörapporten, 2001a, translation by the author). Agroethanol AB had a tax exemption for ethanol until the end of 2003, but all the other companies that had run out of tax exemptions granted in the past were forced to increase their ethanol price (Miljörapporten, 2001a). Miljörapporten reported a reduction in E85 fuel sales for light vehicles by three-quarters in a three-year period (Miljörapporten, 2001e).[83] Thus, the rejection of the tax exemption had dire consequences for the popularity of ethanol, which is also likely to have influenced the ethanol discourse at the time.

What may have influenced the Ministry of Finance to reject support for biofuels was not only the demand for cost-efficient CO_2 reductions, but also the realization that biomass was scarce. According to Fallde et al. (2007), the Environmental policy bill 'Swedish Environmental Quality Objectives: Environmental Policy for a Sustainable Sweden' published in 1998, was the first in which decision makers expressed doubt about the ability of existing biomass resources to aid the greening of the transport sector as well as the heat and energy sector. However, they did not investigate these issues properly and in 2001, when old CO_2 goals had been reached and new ones were being drawn up, this issue was no longer on the political agenda. The new government goal set a CO_2 emission reduction target of 4% by 2008-2012 in relation to the 1990 reference value, and once again this was to be contributed by each sector.

Both the targets set for further CO_2 reductions in the transport sector outlined above, and the announcement by the European Commission of a forthcoming obligation for biofuel implementation in 2001 (see Van Thuijl, Roos & Beurskens, 2003) are likely to have put pressure on the government to grant a general biofuel tax exemption. Eventually, in 2003, the EU announced its biofuel policy, including two policy changes. First, instead of the initial announcement about obligatory biofuel implementation, the EU Biofuel directive (EC, 2003a) set indicative targets of a 2% share for biofuel in the transport sector by 2005 and 5.75% by 2010. Second, a change in the Mineral oil directive (EC, 2003b) to allow EU member states to grant a general biofuel tax exemption of six years or longer to facilitate the implementation of the Biofuel Directive.

As a result of the EU Biofuel Directive, the legitimacy of conventional biofuels, including the ethanol discourse, grew. Consequently, the Budget bill for 2004 suggested that 'CO_2 neutral fuels', such as biofuels, should have a general tax exemption from 2004 to 2008 (Persson & Ringholm, 2003). In recognition of the fact that Swedish biofuel actors had an ambition to implement more biofuels than the target set by the Commission, and the room given for tax exemptions by the Commission, it was suggested that Sweden set a biofuel implementation target of 3% instead of 2% for 2005 (Miljödepartementet, 2004; Persson & Messing, 2006).

With the new biofuel implementation targets set out by the Swedish government and stimulated by the EU Biofuel Directive, a debate started about what measures to apply in order to reach these targets. The debate discussed two different routes. The first suggested increased

[83] The decrease in ethanol consumption is also visible in Table 30, however, it is only temporary. Table 30 indicates an increase in consumption from 2003.

use of small-scale blends in fossil fuel, while the second suggested an obligation on pure fuel distribution. I outline the context for these arguments below.

More and more experiments with E10 to E20 ethanol mixes in gasoline were made in the late 1990s (see Chapter 7). Meanwhile, since 1996, the EU had been working on an Auto/Oil Directive to set a quality standard for gasoline. This directive had gone through the political decision apparatus in the EU and Sweden. During the final decision round in 1999, it became clear that the new gasoline standard would not accept an ethanol blend of over 5% in gasoline. According to parliament, 'it was too late to change anything' and thus Sweden had to accept the ban on ethanol blends above 5% despite ongoing experiments with 10% blends and advanced plans for even higher blends (Miljörapporten, 2000c, translation by the author). The ban on higher ethanol blends was due to strong lobbying by the European car industry, which worried that higher ethanol mixes would result in lower durability of older vehicle models and doubted that they would result in environmental gains. After the implementation of the Auto/Oil Directive, in January 2000, parliament instructed the government to lobby the European Commission to gain an exemption from the law restricting the ethanol mix to 5% (Miljörapporten, 2000a). However, the European Commission gave no response to this demand.

In 2002, as the intentions of the EU Directive on Biofuels was becoming clearer, the Social Democrats, the Left Party and the Environment Party suggested meeting the biofuel implementation targets by means of a law that obliged filling stations to sell pure biofuel from January 2005. Other parliament members initially rejected this proposal, but it received renewed interest once the Biofuel Directive became a fact in 2003 (Miljödepartementet, 2004). Eventually, the government set up a Commission for the Investigation of Renewable Vehicle Fuels to investigate the issue further. This commission was fairly positive about the installation of pure fuel pumps, and E85 pumps in particular, at about 50% of the fuel stations in the country. They argued that ethanol fuel was the only realistic alternative for large-scale distribution in a short time frame. However, the oil distribution companies were negative about the suggestion. They wanted to expand the alternative fuel supply in tandem with increasing demand. According to the Commission, however, the approach suggested by the oil distribution companies would create a catch 22 (Lindemalm, 2004a).

To prevent the implementation of a biofuel pump obligation, the oil companies formed a lobby with a selection of biofuel actors and scientists. Together they argued that the increased use of small-scale blends in fossil fuels was preferable from both a cost-efficiency and an environmental perspective, and thus the government should put more energy into lobbying the European Commission to permit higher blends instead of pushing the pump law (Ringström, 2005a; Miljörapporten, 2003f). In addition to the arguments of the anti-biofuel pump obligation lobby, several national authorities (the Environmental Protection Agency, the Energy Authority, the Swedish Road Administration and VINNOVA) expressed scepticism about the success of an ethanol pump obligation. Organizations such as Green Motorists were afraid that such an obligation would be counterproductive for ethanol development. These ethanol actors, which were expected to profit from the new law, also expressed objections although less severe. According to Werling, CEO at Agroethanol, the law was not good since 'low mixes are a better choice' (Lindemalm, 2004a). Jan Lindstedt, previously at SSEU and now part of the management of the ethanol project the BioFuel Region, was also hesitant. He argued that these kinds of developments should not be forced (Miljörapporten, 2003f). However, some argued that biogas would face the most negative consequences and lose market opportunities to ethanol due to the increasingly cheap ethanol infrastructure that the pump law would result in. Despite the strong criticism, the Environmental Party continued to promote the pump law (Lindemalm, 2004a).

The lobbying against the biofuel pump obligation did not manage stop its implementation. However, a slightly revised proposal was put forward in 2005 (Persson & Sommestad, 2005) that restricted the E85 fuel supply obligation to larger fuel stations at the initial stage and smaller stations in the future. The bill was voted through parliament and its successive implementation was carried out from 2006 to 2010 (Persson & Messing, 2006). This decision showed that the ambition to increase the percentage blend of biofuel in diesel and gasoline remained. The Swedish lobby at the EU level would continue throughout the period (Sandebring, 2004; Kommissionen mot oljeberoende, 2006).

The LIP was given a follow-up programme, the Climate Investment Programme (KLIMP), geared towards climate change mitigation measures at the municipal level, which ran from 2003 to 2008 (Naturvårdsverket, 2011a). Like the LIP projects, KLIMP funds for transport fuels went predominantly to biogas and only to a few ethanol projects (Naturvårdsverket, 2011b). In the Budget bill for 2006 (Persson & Nuder, 2005), it was decided that tax exemptions for biofuels would be prolonged after 2008 until 2013. Despite all these measures, the government did not manage to reach the goal set of 3% biofuel implementation by 2005. Depending on which source is consulted, a share of either 2.7% or 2.3% biofuel implementation was reached. However, this was still above the EU norm of 2% and Sweden aimed to reaching the 5.75% indicative target for 2010 (Jonsson, 2007). In fact, continued biofuel development was stimulated not only by the EU Biofuel Directive, but also by Prime Minister Göran Persson, who continued to promote a green ambition for Sweden. In November 2005, he stated that Sweden should be independent of oil by 2020. While increasing concern over climate change was one of the motives behind this goal, the main one was to become independent of oil that became more expensive. According to Persson, peak oil had been reached and the oil price would only go higher (Bengtsson, 2005).[84] As is shown in Figure 10, the price of oil has kept rising. The Commission on Oil Independence (Kommissionen mot oljeberoende, 2006), which was set up by the government in December 2005, argued that Persson's 2020 goal to become independent of oil was not within reach.

Alongside increased support for crop-based ethanol after the publication of the EU Biofuel Directive, there seems to have been support for the cellulose ethanol as well, given the funding from the ethanol R&D programme that led to the realization of a cellulose ethanol pilot plant in 2004 (see the section on Swedish ethanol experiments).

Despite the positive development patterns, an anti-ethanol lobby started to threaten both crop and cellulose ethanol fuel alternatives. As is mentioned in the previous period, initial criticism had been voiced against the policy focus on ethanol by a variety of actors in 1997 (Kommunikationskommittén, 1997: appendix). Methanol proponents were particularly critical. They argued that there was favouritism towards ethanol in policy, but also about the quality of ethanol fuel (Miljörapporten, 1998c). In order to further synthetic gas based fuels, organized criticism appeared of ethanol at the political level, led by the Swedish Road Administration (Miljörapporten, 1999c).

Criticism of the energy efficiency and climate effects of bioenergy and biofuels was also increasing internationally. For instance, the problems of deforestation in Brazil and Indonesia due to higher demand for biomass were on the agenda at Bill Clinton's climate seminar in 2007. Another example was the Nobel Prize winner for chemistry, Paul J Crutzen,

[84] The underlying motive was to change the focus of energy politics from a promise to decommission nuclear energy to a move away from of fossil energy (Bengtsson, 2005).

who together with other researchers published a paper in 2007, arguing that conventional biofuels such as rapeseed diesel and ethanol from corn emitted more greenhouse gases than their fossil fuel alternatives. Only second-generation fuels based on wood were considered better from a greenhouse emission perspective, since they were said to use hardly any fertilizers (Fock, 2007a). In addition, the OECD (Doornbosch & Steenblik, 2007) was highly critical of EU policy. According to the OECD, ineffective government support for biofuels would increase food prices and threaten the rain forests, while contributing very little to improve the climate. Like Crutzen, the opinion of the OECD was that investments should go on the development of second-generation fuels that were more efficient.

The biomass for fuels versus energy and heat debate returned to the agenda in 2005, raising criticism of the one-sided focus on ethanol in Swedish biofuel politics. Kågesson (2005) and Azar (Azar, 2006a; Azar, 2006b) at Chalmers University of Technology were the most visible in this debate, arguing that the high level of financial support for crop ethanol was wrong for several reasons. First, energy and heat production was a more energy efficient use of biomass than ethanol production. Second, there was not sufficient biomass for both energy production and liquid fuel production, which made the waste of energy in the biofuel sector even worse. Third, they addressed the environmental problems with the production of ethanol, referring in particular to the negative effect that tropical biomass had on biodiversity, such as in the case of Brazilian ethanol mainly used in Sweden (ibid.). They referred to reports from international organizations such as Food First Information & Action Network and Greenpeace, which argue that ethanol production in Brazil leads to increased monoculture and thus reduced biodiversity. Moreover, the cultivation was also harmful for humans due to the extremely harsh working conditions (Thuresson, 2006). Based on this line of argument, Kågesson (2005) and Azar (2006a) proposed spending funds on second-generation fuels to reduce such problems. However, Azar (2006a) stressed that attention should not be given to cellulose ethanol alone. According to Azar, Brazilian sugar cane ethanol could become an environmentally friendly fuel if produced in the right way. This statement was supported by some actors against ethanol (e.g. Doornbosch & Steenblik, 2007; Hådell, 2005; Kågesson in: Samuelsson, 2005e). In line with this, Azar argued for aid to developing countries to help them exploit their biomass resources in a more sustainable way (Azar, 2006a).

Kågesson's and Azar's criticisms of conventional ethanol indicate attention on a new issue in the biofuel debate in 2005, that is, the impact of large scale tropical biofuel production on biodiversity. What was new with this biodiversity issue was the international character of the discourse. An second international debate was the food versus fuel debate, which contributed to an anti-biofuel discourse that reached Sweden in 2006 (see: Azar, 2006b; Azar, 2007). One of the more famous examples of the debate over ethanol was the shortage of food in Mexico due to the decision of the USA to use their surplus corn for domestic ethanol production instead of continuing their practice of dumping the surplus on the world market. These developments resulted in an international anti-biofuel coalition, particularly critical of first-generation fuels such as crop ethanol.

While it might be expected that the worldwide criticism of ethanol would harm the ethanol discourse, contemporary ethanol developments were surprisingly positive. Alongside the government decision to continue the tax exemption to 2013, there was great support for the continued subsidy for domestic ethanol production. The primary motive for continued subsidies was no longer environmental concerns, but regional development – as seen in the argument of a majority of the members of the Oil Commission (Kommissionen mot oljeberoende, 2006) that beneficial tolls and tariffs to protect domestic ethanol production and related industries should be kept. Only one commission member, Azar, argued that the elimination of tolls and tariffs on developing countries would stimulate the use of more environmentally friendly biofuel, such as Brazilian ethanol, and give these countries a chance to profit from this new industry (Kommissionen mot oljeberoende, 2006). Biofuel development and implementation was also stimulated by the EU Biofuel Directive, which had set indicative targets for increasing biofuel implementation. In fact, in early 2007 the EU announced the introduction of a binding target of 10% biofuels in 2020 (EU, 2007).

Additional proof that the ethanol discourse was doing well was the positive market expansion of ethanol FFV that continued to reach new sales records. The ethanol production and import company, Sekab, the ethanol vehicle industry (Scania, Saab and Ford) and the Minister of Environment, Carlstedt, referred to the explosive FFV increase as the 'Swedish environmental vehicle wonder' – something that foreign politicians, industry and environmental groups were interested in copying. Sweden was leading in both the development of heavy and light ethanol vehicle technology (Östling et al., 2006, translation by the author). Part of the success was a result of local policy incentives for environmental vehicles in large Swedish cities such as Gothenburg and Malmö (Lindemalm, 2003), but in particular by the Stockholm authorities and their Clean Vehicles Project. Examples included successful local FFV procurements as well as local support measures for FFVs and other environmental vehicles, such as free parking from 2005 and a congestion tax exemption from 2006 (Birath & Pädam, 2010).

The positive FFV trend led the ethanol promoter Carstedt to argue that the EU goal of 10% renewable transport fuels by 2020 could be reached using ethanol alone. He contributed to the existing discourse of ethanol as the best substitute for oil by stating: 'Ethanol is, within this time span, the only substitute for gasoline and diesel that has the prerequisite to supply the market with the large volumes that are required. Additionally, it is the most economic and simple solution' (Fock, 2007c, translation by the author). The criticisms raised in relation to ethanol vehicles, particularly buses were, according to ethanol project evaluators Karlsson and Jalmby (2007), old problems with early models that had long been resolved.

The only barrier that the ethanol lobby recognized was the high price of ethanol, which in 2006 meant that ethanol was more costly than gasoline (Östling et al., 2006). While the anti-biofuel lobby linked the ethanol price increase to competition with food, as mentioned above, ethanol proponents stressed other reasons. According to Samuelsson (2007d), the domestic crop ethanol industry blamed this on the high oil price which led to high wheat and thus high ethanol prices. However, ethanol producers and importers such as Sekab and the ethanol vehicle producers (Östling et al., 2006) argued that the relatively high ethanol price was due to increased demand for ethanol on the world market in combination with a reduction in the gasoline price due to a gasoline surplus caused by the vehicle propulsion shift from gasoline to diesel. To combat the increase in ethanol price, they asked the government to take away the only tax remaining on ethanol fuel – value added tax (VAT) (Östling et al., 2006; Westergård, 2006c).

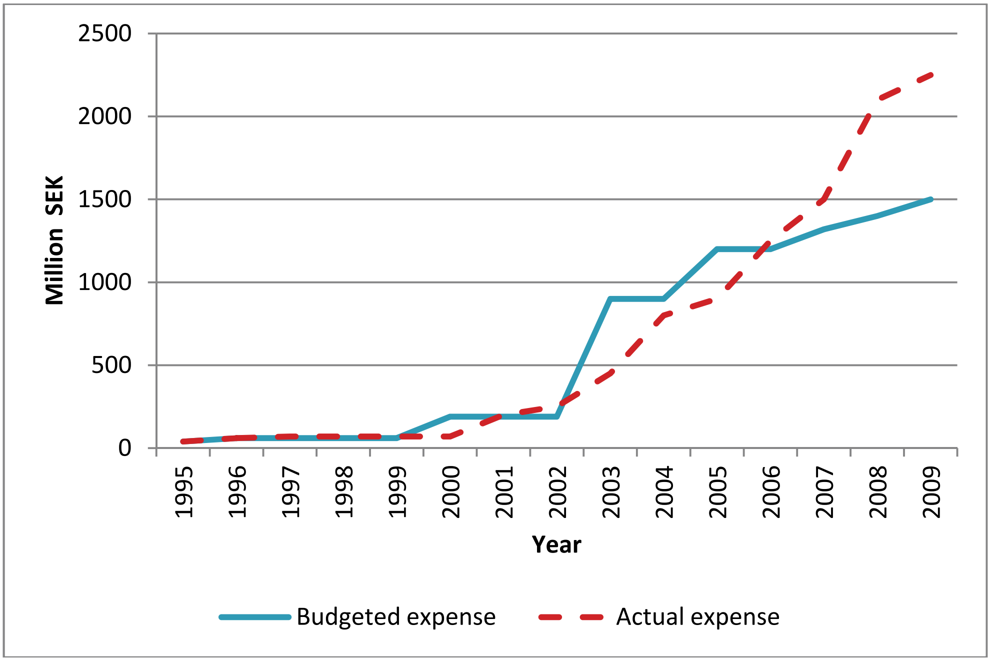

Figure 14: Budgeted and actual tax loss due to biofuel tax exemption, 1995-2009
Source: Swedish National Audit Office (Riksrevisionen, 2011: 47).[85]

The request for increased tax exemptions could be interpreted as rather dramatic, considering the high costs of the tax exemptions already granted. According to Figure 14, the cost of tax exemptions had increased steadily since 2000 and reached annual cost of SEK 1.5 billion by 2007.

The R&D funding programme for the development of cellulose ethanol, Ethanol from Forest Feedstock, had resulted in the inauguration of a pilot plant in 2004 (Westergård, 2006c). However, the subsidy programme was ending the same year and researchers at Lund University, the BFR and Sekab started lobbying for new programme funds (Falk, 2006). Ethanol vehicle producers like Volvo, Ford and Scania as well as the Minister of the Environment, Carlstedt, joined the lobby at a later stage, stressing that securing a future supply of domestic ethanol was even more pressing now when ethanol was scarce leading to high prices (Östling et al., 2006). Two arguments dominated the lobby for further support for cellulose ethanol. The first related to the creation of employment and linked up with the regional development discourse. References were made to new jobs already created in the ethanol vehicle industry and the great potential for the future from securing future ethanol supply by supporting the construction of a cellulose ethanol industry (Östling et al., 2006). The second argument was an attempt to link up with a national economic growth and innovation discourse by referring to Sweden as a forerunner. The unique head start that Sweden had in ethanol vehicle technology and cellulose ethanol production was highlighted, and that continued government investments, as it had previously done for the Swedish paper and pulp,

[85] The data originates from various government documents indicating budgeted expenses and estimates of costs based on actual biofuel (ethanol and biodiesel only) consumption in 1995-2009 (Riksrevisionen, 2011).

vehicle and telecom industries, would secure great economic opportunities for Sweden in the future (Östling et al., 2006; Falk, 2006; Westergård, 2006c).

In comparison with these strong arguments for supporting cellulose ethanol, the coalition actors' statements on the potential for cellulose ethanol to substitute for oil had become more muted. For instance, Carstedt at BAFF, who in 2003 had argued that Sweden had sufficient biomass for ethanol production to substitute for fossil fuels in the transport sector, was much more modest in 2006 when he argued that other solutions were necessary in addition to ethanol in order to substitute oil. He also stated that Sweden could not reach the 2020 goal of oil independence set out by Prime Minister Persson. He argued: 'we have started the process far too late, just phasing out the current vehicle pool will take 15 to 20 years' (Westergård, 2006c, translation by the author). Hence, despite the strong lobby for cellulose ethanol, the temporary discontinuance of funding and the statement by Carstedt shows a weakening cellulose ethanol discourse.

However, the lobbying resulted in a follow-up cellulose ethanol programme in 2007. The programme aimed to scale-up the current pilot plant to a demonstration plant (Energimagasinet, 2007), but the cellulose ethanol actors put these plans temporarily on hold. The reasons given for the delays in commercialization of the cellulose ethanol plant were increased technical problems and competition for wood feedstock. Instead, cellulose ethanol actors made plans to support the market with increasingly competitive ethanol by setting up sugar cane ethanol production in Tanzania (Fock, 2007d). This makes it likely that there was a parallel between the shift to an increasingly humble cellulose ethanol discourse and the technical problems in the ethanol project.

The sugar cane projects in Africa did not prove a good alternative. The projects received heavy criticism from scientists and NGOs for being both environmentally and socially damaging, and in early 2009 SEKAB withdrew from the project (Benjaminsen et al., 2009; Factwise, 2009; Biogas Öst, 2009). The growing international anti-biofuel lobby is likely to have stimulated the harsh reactions from scientists and NGOs.

The strong anti-biofuel lobby pushed Sekab to take additional action. From early 2007, Sekab worked on certification of the Brazilian ethanol imported to Sweden in collaboration with Brazilian producers in order to safeguard environmentally and socially acceptable ethanol distribution in Sweden. These activities resulted in certified Brazilian ethanol on the Swedish market from August 2008 onwards (SEKAB, 2011b; SEKAB, 2008b). According to Sekab's press release: 'Swedish SEKAB becomes first in the world to deliver verified sustainable ethanol' (SEKAB, 2008b, translation by the author). The criteria used by Sekab were in line with the criteria developed at the EU level in cooperation with UN and NGOs (ibid.). The development of sustainable criteria not only by local, but also by global actors indicates the international width of the anti-biofuel discourse.

The effects of the anti-biofuel discourse at the EU policy level were swift policy changes. For instance, the European Commission had in January 2007 announced a binding biofuel implementation target of 10% for 2020. However, due to the anti-biofuel debate the plan was withdrawn in July 2008 (Harrison, 2008). A revised directive was ready in 2009 (EC, 2009), in which the focus on biofuels had shifted to renewable fuels implementation. Renewable fuels meant either cost-efficient second-generation biofuels or green electricity and hydrogen options which could meet the 10% target for 2020. To avoid supporting less efficient and more environmentally harmful fuels, the directive prescribed sustainability criteria which the renewable fuels should meet, and advanced transport biofuels based on waste, residues, non-food cellulose materials and ligno-cellulose were encouraged. The stimuli meant that electric vehicles based on biomass or other renewable energy counted 2.5 times more, and advanced biofuels counted twice as much as conventional biofuels in meeting the implementation target (EC, 2009).

The conditions under which the EU directive was to be met were arguably a prime mover in the development of a Swedish law by which the producers and distributers of biofuels had to report on the degree to which their biofuels met certain sustainability criteria . The law started operation in 2012 (Energimyndigheten, 2011). By these means, more actors than just Sekab would be forced to track the sustainability of biofuels throughout the whole production chain.

8.1.4. Ethanol discourse analysis, 1998-2010

Ethanol					
Policy	**Level**	**Year**	**Type**	**Size SEK**	**Explanation**
Ethanol bus niche	Municipalities	1997-	Field trial		Expansion of buses from 100 in 1997 to 510 in 2008.
E10 in gasoline	industry	1997-2000	Field trial		10% ethanol mix in gasoline introduced by OK/Q8.
E5 in gasoline	EU	2000-	Regulation		EU regulation limited mix to 5%, ends OK/Q8's E10 trial.
	Government	2003-	Field trial		5% ethanol in all gasoline of OK /Q8, other fuel companies follow, stimulated by general ethanol tax exemption from 2003.
BAFF		1999-	network		SSEU changes name to Bio Alcohol Fuel Foundation (BAFF)
FFVs	Municipalities, government	1999-2006	Field trial	Government, municipalities and industry through LIP, EU ZEUS funds, Leasing vehicle subsidies	Common procurement 3000 FFVs delivered in 2001, and 5000 FFVs delivered in 2003. Clean Vehicles Stockholm, Swedish Energy Agency, Ford, Swedish Delegation for Sustainable Technology.
Crop ethanol plant	Government, industry	2001-	Market expansion	expected budget 450 million	Agroethanol-wheat ethanol plant Norrköping starts production 2001. Initial tax exemption 1999-2003 prolonged.
	Industry	2008-	Production	1 B	2008 second Agroetanol plant
Local incentives	Municipality	2002-		Trendsetter EU programme, LIP funds	Clean Vehicles Stockholm stimulates environmental vehicles (Free parking in Stockholm from May 2005-January 2009, etc.). Similar measures in Gothenburg, but limited information about year and funding.
Import		2004-	Regulation		From 2004 onwards, everyone allowed to import ethanol.
Fuel pumps	Industry	2000-			From 2000 onwards, additional fuel distribution companies to OK/Q8 start E85 distribution.
	Government	2005-	Regulation		2005 biofuel pump law leads to successive increase in E85 pumps
Cellulose ethanol R&D program	Government	1998-2004	R&D	217 million	2nd period. Contributed to the set up of a pilot plant in 2004 and first ethanol production in 2005.
	Government	2007-2010	R&D	144 million	3rd period with the aim to further cellulose ethanol production technology.

Table 32: Ethanol policy development, 1998-2010

Biofuel	**Discourse**	**Mobilization/ impact of wider discourses, events and policies.**	**Discourse coalition**	**Target audience**	**Key activities, strategies**	**Resulting space/policy creation or disruption**
Conventional and advanced ethanol production, and use in low and high blends.	Still argued to be the best fuel alternative to reduce global emissions on a large scale in the short and long term, and to improve regional development	Successful embedding in global environmental and regional development discourse. Embedding in self-sufficiency discourse was also successful, but secondary. Events such as the Biofuel Directive had a positive impact, while the anti-biofuel discourse had a negative impact	Farmers' organizations, municipalities, the chemical industry still central actors, of which some cooperated within SSEU	Lobbying was initially oriented to the government to prolong tax exemptions and later the public for legitimacy	Lobbying by means of campaigns (FFV use), the media, scientific reports and political arenas. Strategies used extended the ethanol bridging argument to other biofuels, the use of sustainability certificates.	Continued ethanol tax exemptions of increasing amounts of ethanol, local and national subsidies for FFVs, a biofuel pump law, and support for domestic production plant and cellulose ethanol R&D. Only temporary slowdown in subsidies at the turn of the century and the late 2000s. General increase in institutionalization of standards and regulations.

As in the previous period, the ethanol discourse was still presenting ethanol as the best and most realistic alternative fuel for fossil fuel substitution in both the short and the long term. Ethanol was still seen as particularly beneficial for CO_2 emissions reduction, but also for regional economic development and for reducing dependency on oil. While some still defended ethanol as the only future fuel, a new idea gaining ground in the 2000s was the need for complementary alternative fuels to substitute for fossil fuels. The embedding of the ethanol discourse in the expanding regional development discourse, the self-sufficiency discourse, with the increased acknowledgement of peak oil, and the increasingly global environmental discourse facilitated continued policy support in this period. An additional contribution to discourse stability was the preparation and publication of the EU Biofuel Directive. However, the growth of the anti-biofuel discourse at the end of the period challenged the ethanol discourse.

As in the previous period, both conventional and advanced fuel promoters such as farmers' organizations, municipalities and the chemical industry were central actors, some of which cooperated within SSEU – which changed its name to BAFF. A new prominent actor was the local authority initiative Clean Vehicles Stockholm, which took a more active role in promoting FFVs in the mid-2000s. In addition to the use of various media, scientific reports and the national and EU policy arena for various lobbying activities, specific strategies were applied to counter the growing criticism of ethanol from the synfuel and anti-biofuel discourse. The main strategy was to expand the bridging argument to other biofuels in this period. This was seen in the collaboration with RME and the failed attempt to team up with the synfuel discourse by the setting up of BAFF as a means to meet the increasing ethanol critique. A complementary strategy to counter criticism at the end of the period was the introduction of sustainable certification. These changing strategies went hand in hand with a changing coalition structure. Initially, when the coalition used bridging arguments, it demonstrated coalition coherence. However, ethanol discourse coherence declined towards the end of the period. With the escalating criticism from the anti-biofuel discourse, ethanol coalition actors increasingly defended their own projects instead of ethanol as a whole, which is reflected in the different levels of success in defending sugar cane ethanol from Africa and Brazil.

Generally, support for ethanol increased during this period, indicated by increased government tax exemptions, increased subsidies for FFVs, a biofuel pump law and various incentives from local authorities. This contributed to an increased institutionalization in terms of fuel standards, infrastructure and vehicles. However, discourse instability went hand in hand with pauses in tax exemptions in the early 2000s and R&D investment in the mid-2000s, as well as a reduction in cognitive support in the late 2000s. The less stable periods can be connected to the criticism of ethanol by the synfuel and the anti-biofuel discourses.

8.2. BIOGAS MARKET EXPANSION THROUGH LOCAL NETWORKS, 1998-2010

This section describes continued biogas development in the period 1998-2010. First, I present the development of the biogas niche followed by an SNM analysis. Second, I describe the political processes leading up to biogas policy followed by a discourse analysis.

8.2.1. Biogas niche development, 1998-2010

Positive experience of biogas experiments and positive evaluations of biogas as the most environmentally friendly vehicle fuel set the stage for biogas development this period. While developments continued in the biogas cluster around Linköping, other more independent biogas networks also appeared in this period. A few examples are: Göteborg and the neighbouring towns of Trollhättan and Borås, which started cooperating in the Biogas Väst (or West) network, the general Stockholm network Clean Vehicles Stockholm, which took shape in the previous period, and a network around the experiments in Kristianstad, Biogas Syd (or South). These local clusters were particularly for biogas that had benefits for local waste management. Hence, the spread of biogas was connected to existing municipal sewage plants or waste recycling projects where an upgraded facility could be built for exploitation of the gas as vehicle fuel.

Biogas Väst was the main driver of biogas expansion in this period. In the previous period, biogas production and use had been limited to Gryaab's installation and a small gas vehicle fleet in Gothenburg and Trollhättan. However, in this period public authorities at the regional and municipal levels as well as private sector actors such as Volvo took over development in the west of Sweden (Ahlbäck, 2003). These actors were part of the world's first regional cooperation for biogas as a vehicle fuel, which was set up in 2001 at the initiative of local politicians (Biogas Väst, 2008; Ahlbäck, 2003).

An informal inventory, set up by politicians from Gothenburg, Trollhättan and Borås, was the starting point for Biogas Väst. The inventory on how the regional bioenergy resources could best be accounted for concluded that biogas development was particularly promising for the region. The arguments behind this conclusion were Trollhättan's previous developments in biogas, the fact that the west of Sweden was the second-largest biogas user after Linköping, the existence of a (natural) gas distribution system and the large potential for the Gothenburg sewage waste company, Ryaverken, to expand biogas production. Even at this stage, the local municipalities in the region reached a consensus that the biogas system should coexist with the natural gas system to enable maximum exploitation of expensive pipeline infrastructure and related distribution systems (Ahlbäck, 2003). This was an active decision to overcome resistance to feeding biogas into the natural gas grid, which was a barrier identified in the previous period.

The project plan was set out in a pre-study in 2001. According to this plan, the Biogas Väst project would run from March 2001 to the end of 2003, and regional expertise would contribute to the project. Business Region Göteborg (BRG), a non-profit organization represented by 13 local municipalities with the aim of increasing regional economic growth and employment, managed the project in cooperation with the other project financers. The financers of the project were the BRG, Volvo, Göteborg Energi AB, the gas distributor Fordonsgas Väst, Gothenburg Transport Office, the Västra Götaland region, the cities of Borås and Trollhättan and the Federation of Swedish Farmers (LRF). The general goal of the project was to contribute to sustainable environmental and economic development. However, according to the project leader of Biogas Väst, Göran Värmby, the increasing employment and trade in the region were primary and supporting local and national environmental goals was secondary. According to Värmby, these goals were to be reached by stimulating demand for biogas vehicles, as well as biogas production and distribution in the region. The project would cooperate with natural gas in order to increase the biogas market. In the long-term, however, the biogas market was to be self-sustaining. Translated into practice, this implied an increase of: (i) filling stations from five to 25' (ii) methane powered vehicles (hence, not necessary bio-based) from 800 to 2500; and (iii) biogas use in the transport sector from 9 GWh to 120 GWh (Ahlbäck, 2003).

A number of actors contributed to the activities of Biogas Väst, including actors that were not directly members of the network. The producers of biogas were the public companies Gryaab in Gothenburg and Traab and Tekniska Förvaltningen in Trollhättan. The distributors were Göteborg Energi AB, which owned the pipeline, as well as Fordonsgas Väst, which built and owned the filling stations in the region. To use the gas, both Volvo and Saab had provided gas powered buses with support from municipalities in the early 1990s, and Volvo provided gas cars. The fact that Volvo was the only one providing gas cars on the Swedish market (Ahlbäck, 2003), and a pause in gas vehicle production at Volvo in 1999-2001 as a result of the takeover of the company by Ford (Sandén & Jonasson, 2005), is likely to have led the network actors to seek additional gas vehicles. To increase the variety of gas vehicles, Gatubolaget in Gothenburg started a search for the small and medium-sized vehicles demanded by users. Eventually, in 2001, a local Opel dealer in Gothenburg, Bilstudion, delivered an Opel Zafira gas model. In 2003, other brands, such as Volkswagen and Mercedes, offered models on the Swedish market. Most of the vehicles were, like the original Volvo model, hybrid bi-fuel vehicles with one tank for gas and one tank for gasoline (Ahlbäck, 2003). For the Biogas Väst region, this contributed to an increase in the gas vehicle pool from 788 in 2001 to 2165 in 2004 (Norrman, Belhaj, Arnell, Svensén, & Larsson, 2005a).

The increase in gas vehicle sales and the variety of models probably benefitted from the development of a biogas standard and various incentives at both the national and the local level. At the request of the Swedish vehicle manufacturers, Volvo and Saab, a national biogas standard was set in 1999. The standard for biogas was adapted to fit the current designs for natural gas fuel and engine systems, and thus also for injecting biogas into the natural gas grid (Persson, Jönsson & Wellinger, 2006). The extensive work on a biogas standard carried out since the early 1990s by the KFB working group (see the previous biogas period) and various field experiments are likely to have contributed to this standard. The agreement on a national standard is likely to have eased the previous barriers to the distribution of biogas in natural gas pipelines.

Alongside the change in standard, the government implemented various legal incentives during this period. One example is changes to the fringe benefit tax on leasing vehicles or company cars, which was decreased successively for biogas vehicles in 2000 and 2002. The intention of this tax reduction was to reduce the price of environmental vehicles to that of conventional cars. The fact that biogas vehicles gained from these benefits was partly thanks to the lobbying of the actors behind the Biogas Väst network (Ahlbäck, 2003). With the prolongation of the fringe benefit tax for alternative fuel cars in 2006, gas vehicles gained an additional tax reduction of 20%.[86] This was similar to the tax reduction that EVs had gained previously. Ethanol vehicles, however, did not enjoy the additional tax reduction (Persson & Nuder, 2005). Another government incentive that benefitted biogas vehicles at the end of this period was a rebate of SEK 10 000 to private individuals who bought a clean vehicle in the

[86] However, the maximum reduction for a biogas vehicle was SEK 16 000 annually (Persson & Nuder, 2005)

period 2007 - 2009 (Birath & Pädam, 2010). Moreover, Biogas Väst developed local incentives for gas vehicles, such as free parking permits for environmentally friendly vehicles as well as keeping a fixed price on vehicle gas during an introduction period. This, together with the ability to use the natural gas infrastructure, were the main reasons for a vehicle gas price in Trollhättan in the Gothenburg region that was 39% cheaper than Stockholm (Ahlbäck, 2003).[87]

The 2165 biogas vehicles, 18 gas filling stations and 38 GWh of biogas production in 2003 did not meet the goals of Biogas Västfor the region of Västra Götaland . The production goal was especially distant. Despite these shortcomings, the Biogas Väst project partners decided to extend the project. The biogas production goal of 120 GWh in 2003 was moved to 2007, while the number of refuelling stations was raised to 35 and implementation of vehicles to 7000 (Norrman et al., 2005a). With 36 gas refuelling stations and about 7000 vehicles in 2008 the goals were reached for both refuelling and gas vehicles (Biogas Väst, 2008). However, once again the production target was lagging behind. Even by 2009, production in the region was 100 GWh, of which only 60 GWh was produced by Gryab in Gothenburg (Biogas Öst, 2011; Held et al., 2008; Held et al., 2008). The total amount of gas used in 2008, including natural gas, substituted for 18 million litres of gasoline (Biogas Väst, 2008). Despite the shortcomings with regard to biogas production, Biogas Väst (2008) argued that the wider Gothenburg region had the best infrastructure in the country. Overall investment in biogas infrastructure, facilities, refuelling stations and pipelines in the region to 2007 was approximately SEK 670 million. Approximately SEK 1.8-2 billion was spent on both light and heavy gas vehicles (Biogas Väst, 2008).

Table 33 indicates a steady growth of gas vehicles, distribution and use in Sweden in this period. Of all vehicles, the implementation of light vehicles accelerated the most in this period. Successive vehicle tax reductions and local incentives by regional actors such as Biogas Väst are likely to have stimulated this acceleration. The attraction of additional actors, such as vehicle producers in addition to Volvo post 2001, is another factor. Comparing the data with the figures for gas vehicles running in the Gothenburg region presented in the text above, 51% of all Swedish gas vehicles were running in the Gothenburg region in 2003 and 41% in 2008. This shows the leading position of the region in gas propulsion.

The large number of gas vehicles and the many incentives stimulating them did not necessarily foster biogas use, since all gas vehicles could run on natural gas as well and usually had a bi-fuel system which made gasoline propulsion possible. According to Ahlbäck (2003), a local incentive to promote biogas production and use was the 'green gas principle', which was picked up and used in the green electricity field. The principle was a way to overcome the high cost of establishing distribution by means of pipelines or trucks to filling stations for small-scale biogas production in locations where a natural gas distribution system was available. Hence, the amount of natural gas sold as transport fuel was replaced with an equal amount of biogas in another sector, e.g. for heat and electricity production. In the case of Gothenburg, Fordonsgas Väst paid Göteborg Energi AB for this exchange service (Ahlbäck, 2003). Alongside the great ambitions of the Biogas Väst network to increase the biogas market share, the LIP and KLIMP funds enabled the increase of biogas production. According to Held et al. (2008), the expansion of biogas production and upgrading at Gryaab in Gothenburg was one example. Gryaab installed a co-digestion and modern upgrading facility, Cooab, which was one of the largest upgrading facilities in the world. The Gothenburg project partners made big investments, which were matched by the LIP and KLIMP subsidies. The cost of the

[87] According to 2003 data, the price of vehicle gas was 5.50 SEK/m^3 in Trollhättan and about 9 SEK/m^3 in Stockholm (Ahlbäck, 2003)

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
No of vehicles:													
Light	759	1008	1292	1479	2712	3575	4519	6965	11024	13407	15642	21749	30105
Heavy	55	84	103	121	178	191	225	276	338	369	397	412	499
Buses	265	282	330	400	419	482	554	656	757	760	849	963	1434
Total	1079	1374	1725	2000	3309	4248	5298	7897	12119	14536	16888	23124	32038
No of distribution locations													
Public	12	15	18	21	29	35	47	62	70	86	92	105	122
Private, bus	7	7	8	10	10	13	18	23	27	29	30	29	45
Total	19	22	26	31	39	48	65	85	97	115	122	134	167
Sold volume (in 1000 Nm3)													
Natural gas	7086	7552	9010	10369	11300	14087	15943	19398	20140	25213	24386	25108	33666
Biogas	2776	3783	4940	6309	8825	11347	12929	16052	23716	28423	33740	43533	59147
Total	9862	11335	13950	16678	20125	25434	28872	35450	43856	53636	58126	68641	92813

Table 33: Number of gas vehicles and distribution pumps, and fuel consumed, 1995-2010
Source: Energigas Sverige, Bil Sweden and Statistics Sweden

upgrading facility at Gryyab in 2007 was SEK 40 million, of which SEK 9 million was received in KLIMP subsidies (Held et al., 2008).

For the development of biogas vehicles, biogas production and infrastructure there were also substantial funds from both the LIP and the KLIMP programmes, which demanded matching funds from the applicants (Held et al., 2008). The LIP programme ran between 1998 and 2002, and had a total budget of SEK 6.2 billion. Of this, SEK 750 million was spent on so-called environmental vehicles, of which SEK 150 million was spent by LIP and SEK 600 million was matching funds. The LIP was particularly beneficial for biogas development. Of the 1500 alternative fuel vehicles funded, 1100 were biogas vehicles. Of the 18 alternative fuel pumps awarded LIP funds, 16 were biogas pumps. For distribution, funding was granted to pipelines to feed into the natural gas infrastructure or refuelling stations. Regarding production and upgrading of biogas, SEK 360 million was granted of which approximately 260 million was used (Rehnlund et al., 2004). The follow-up programme, KLIMP, ran between 2003 and 2008 with a total budget of SEK 1.8 billion. Almost 200 projects were related to biogas for the transport sector, a share equal to SEK 622 million of KLIMP subsidies and SEK 2 640 million in matching funds (Tamm & Fransso, 2011). While municipalities were the only ones able to apply for LIP funds (Rehnlund et al., 2004), KLIMP funds were available to various local applicants. However, a majority of the biogas projects in the KLIMP programme had municipalities or municipally owned companies as project leaders (Tamm & Fransso, 2011). This makes it likely that interest in biogas among municipalities was high. This is not that surprising, given that processing waste, recycling and reducing local emissions is part of the responsibility of municipalities.

Tax exemptions for company cars and LIP funds were available for all projects, and Stockholm city like Biogas Väst had a variety of local incentives for biogas vehicle implementation. In Stockholm, both Stockholm City and Stockholm Vatten AB, responsible for the distribution of drinking water and sewage waste, had an interest in increasing biogas vehicle use for reasons of environmental improvement (Held et al., 2008). As in the case of ethanol vehicles, Clean Vehicles Stockholm managed the ambitions of the local authorities to expand the biogas vehicle fleet in Stockholm (Rahm et al., 1997; Held et al., 2008). Hence, Clean Vehicles Stockholm aided public and private companies to gain additional financial support from the EU in order to build their biogas or other environmental vehicle fleets (Held et al., 2008). In addition, as is explained in the ethanol section, goals were set for the implementation of environmental vehicles in the fleets of the Stockholm authorities to set an example for others. In addition, there were two local benefits for biofuel vehicles: free parking in Stockholm city from May 2005 to the end of 2008; and an exemption from congestion tax in the first half of 2006 and from August 2007 to 2012 for vehicles registered before 2009 (Birath & Pädam, 2010). As a result of the many incentives at the national and local levels, the number of biogas vehicles increased steadily from 2004 onwards (Svensson, 2007). Some biogas vehicles were buses, which are likely to have been stimulated by the temporary withdrawal of Scania from ethanol bus production as outlined in the ethanol section. According to Held et al (2008), the local public transport company SL had 50 biogas buses in use in May 2008. The short-term plan was to have 140 biogas buses running for SL (Held et al., 2008).

To meet the need, the Stockholm project constructed additional biogas upgrading facilities at the Bromma and Hendriksdal sewage plants in 2000 and 2003, respectively. While the new upgrading facilities gave a total capacity of 78 000 MWh, production was 55 000 MWh in Stockholm in 2008. Nevertheless, the up-scaling was not fast enough to meet the needs of the expanding Stockholm biogas vehicle fleet. The reason for this was partly continuously changing parameters, e.g. taxes, prices and markets, inhibiting planning for the development and implementation of new biogas production and upgrading technology (Held et al., 2008). Another reason for the lack of sufficient gas was problems at the refuelling stations installed and managed by AGA Gas in collaboration with various fuel distribution companies. The compression technology installed to enable fast refuelling was too weak. While this type of compression was strong enough on the west coast, where sufficient high pressure gas was delivered through the pipeline, it was not efficient enough on the east coast where and the gas supply was lower in relation to demand and low pressure gas was delivered by truck. In 2007 AGA started to install more efficient compressors, which increased the pressure at the refuelling stations and enabled continuous gas filling (Biogas Öst, 2011; Rehnlund, 2010).

Nevertheless, there was no quick solution to the problems of weak compressors and insufficient gas supply. This resulted in a negative biogas image, which was spread beyond Stockholm (Svensson, 2007). This hampered market introduction greatly and was part of the reason why Volvo lost faith in the gas market and stopped producing bi-fuel vehicles in the autumn of 2006. In addition to the local problems, Volvo claimed that there were too few refuelling stations, only 80 in Sweden, which were concentrated in the west coast of Sweden. The 10 000 Volvo bi-fuel vehicles sold in the past 11 years had not been economically profitable and Volvo saw no profit in gas vehicles in the short term. Instead, it believed more in the ethanol vehicles, which were more popular on both the Swedish and the international market (Karlberg, 2006). In late 2008, announcements were made about refitting new Volvo cars to gas propulsion by means of collaboration between Volvo and Alternative Fuel Vehicles (AFV) Sweden AB, in Gothenburg (Hultman, 2008). Again, actors in Gothenburg took the biogas initiative, which indicates the importance of this region for niche development.

Unlike Gothenburg, Stockholm lacked natural gas infrastructure and could not fall back on natural gas supply. Hence, AGA tried to tackle the limited gas supply by transporting gas from Linköping and Gothenburg. However, this was a short-term solution that was not very cost-efficient or environmentally sustainable (Svensson, 2007). More long-term plans were to set up several new upgrading facilities at existing sewage treatment plants. In addition, Stockholm Gas planned to reconstruct parts of the 800-km gas network and connect it to biogas redistribution sites in order to facilitate distribution. The first part of the gas network was expected to be in use by2009. Finally, actors started cooperating to gather investment for increased production and distribution of biogas in the Stockholm region. To resolve the biogas supply problems, Stockholm biogas actors saw the need to involve more actors in a broader geographic area (Held et al., 2008). They set up Biogas Öst, a regional collaboration between the counties of Uppsala, Stockholm Västmanland, Södermanland, Örebro, Östergötland and Gotland, in January 2008. In this way, the collaboration between the biogas projects in Linköping, situated in Östergötland County, Stockholm and Uppsala increased. The inspiration came from the successes of Biogas Väst in biogas development and from funds granted by the government and the EU (Biogas Öst, 2009; Svensson, 2007). The aims of the project were to increase biogas distribution and use, and reach environmental goals with the long term goal of achieving a 10% share for biogas of the transport fuel market by 2020. In addition, the project partners expected to contribute to increased employment and sustainable waste management (Biogas Öst, 2009).

Prior to joining forces with Stockholm in Biogas Öst, developments continued in Linköping. As reported in the previous section, 27 biogas buses were running in 1997. By 1998, the fleet had expanded to 48 biogas buses, and by 2000 60 biogas buses were running. In 2002 the whole bus fleet in the Linköping area was running on biogas. In addition to the fast transition of the bus fleet to biogas, the number of biogas cars, taxis and private company distribution vehicles increased over the years. A local pipeline distributed the biogas from the upgrading facility in Åby to the bus garage and local refuelling stations (Held et al., 2008). Also in Linköping, free parking was used as a local incentive to stimulate the increase in private biogas vehicles in the region (Svensk biogas, 2010). From 2006, there was even a local train running on biogas from Linköping to Västervik. The railway track was not electrified and it was far cheaper to reduce emissions by changing from diesel to biogas than to electrify the track (IEA, 2006). In the same year, 6% of all fuels consumed by citizens of Linköping was biogas, which contributed to the goal of a cleaner inner city environment. Moreover, they had tackled the problem of unpleasant smells using different measures, such as filters, wastewater cleaning and engaging with the public in evaluating the smells (Held et al., 2008).

The fact that Linköping was selling some of its biogas to Stockholm makes it likely that there was no local biogas shortage. According to Held et al. (2008), Svensk Biogas, which was set up in the previous period, installed a new co-digestion plant in Åby in 1997 to reduce both local inner city and global emissions by increasing the use of biogas in buses. According to the 2004 statistics, annual production was 48 GWh of biogas and about 52 000 tonnes of bio fertilizers. Alongside the emissions reductions from the use of biogas, the plant also contributed a sound way of treating the organic waste of the region and replaced fossil-based fertilizers with biological fertilizers. In time, the farmers' cooperative left the ownership of Svensk Biogas to the City of Linköping and Tekniska Verken. However, it remained a supplier of raw material. As a result, the name of the company changed to Svensk Biogas i Linköping AB (Swedish Biogas in Linköping) (IEA, 2006). Since more municipalities had started producing biogas in the Linköping region, the price of raw materials increased (Held et al., 2008). Consequently, the second plant constructed by Svensk Biogas focused on more efficient co-production, in which wastewater from the nearby wheat ethanol plant run by Agroetanol AB was used as feedstock. The plant was constructed in Norrköping close to the ethanol plant and started producing gas and bio fertilizers in 2007 (Svensk biogas, 2011).

Biogas Syd was a third network that started in this period. Biogas upgrading for vehicle use had already started in the county of Skåne before the setting up of the network. Examples are the city of Helsingborg, which together with the local sewage plant, Nordvästra Skånes Renhållningsverk (NRS), owned by six local municipalities, started upgrading biogas to vehicle gas quality in 1997. Capacity increased to 40 000 MWh in 2007, although only 12 000 MWh was actually produced. In 1999, actors in Kristianstad started upgrading and using biogas as a vehicle fuel. The first co-digestion plant, Karpalund, and a local sewage plant provided the gas. Total biogas production was about 46 000 MWh biogas annually. The amount of upgraded biogas that was sold as vehicle fuel via E.ON, was 13 300 MWh in 2007. The rest was used for heating. Like Linköping, there was a local biogas pipeline. The local public transport company Skånetrafiken was an important customer (Held et al., 2008). According to Held (2008), Kristianstad had, next to Linköping, the most complete biogas system in Sweden and thus also in the world, given that Sweden is a leader in the field. Biogas production supplied the whole municipality, and it even exported biogas to filling stations in the nearby towns of Hässleholm, Olofström and Ystad (Held et al., 2008). The success was partly due to cooperation with agrarians, who contributed the feedstock and purchased bio fertilizer, but also to the environmental policy of Kristianstad municipality. In 1998, Kristianstad set out a policy for fossil fuel reduction. A year later, this policy was followed by a declaration to substitute all fossil fuel and eventually in 2005 this was complemented by a climate strategy. This was useful for the project, which had the full support of the local politicians (Held et al, 2008).

Interest in a Biogas Syd network emerged when Bo Mattiasson at Lund University mobilized a group of actors from industry, the university and public organizations for a biogas project proposal in 2003. According to an information campaign organized by the Energy office in Skåne, Biogas Syd started in June 2005. The project was coordinated by the Energy office of the county Skåne (Energikontoret Skåne). Some of the members involved were: the county of Skåne; the farmers' organization, LRF; the Swedish Road Administration; Skånetrafiken; Lund University of Technology; the waste management companies, NSR and SYSAV; energy companies such as E.ON, Lunds energy and Öresundkraft; a variety of municipalities and Energikontoret Sydost. Companies such as Malmbergs, Agellus, Hushållningssällskapet and Kommunförbundet i Skåne were also involved. It was an interest organization that worked both strategically and actively to increase regional production of biogas and its use in order to further economical growth and environmental gains in the region. The members undertook the initial financing for the project (Energikontoret Skåne, 2005).

A great role model was Biogas Väst, but references were also made to the successful advance of biogas production and use in Kristianstad and Helsingborg, as well as the know-how in the field of biogas processing at the local universities – Lund University of Technology and the Swedish University of Agricultural Sciences (Energikontoret Skåne, 2005).

The status of biogas production and distribution in the autumn of 2005 was three upgrading facilities and 13 biogas pumps. The vision for 2015 was increased upgrading facilities and gas pumps in all 33 municipalities in Skåne County. In the autumn of 2005, 1000 of the total 669 000 light vehicles in Skåne were gas vehicles and 100 of 16418 heavy vehicles ran on gas. The vision for 2010 was that 10% of all new light vehicles sold should be gas vehicles. The target for the public sector was 50%. Regarding heavy vehicles, the share of gas vehicles should be 15% of new heavy vehicles, 99% of city buses and 50% of regional buses by 2010. However, by 2013-2015, all the buses in Skåne run by the Skånetrafiken should have gas engines (Energikontoret Skåne, 2005).

Finally, a regional network seemed to emerge in the north of Sweden as well. The government tax reductions for biogas vehicles in 2002 stimulated a general vehicle development in Sweden, although particularly in the north. The government incentives led actors in the cities of Boden and Skellefteå to set up plans for the first biogas upgrading and refuelling station in the region of Norrland (Samuelsson, 2005d). In 2007, two years later than expected, the upgrading and refuelling station was ready in Boden. KLIMP funds aided this development (Held et al., 2008). In Skellefteå, SEK 140 million was invested in building a 'biogas city'. Alongside production and distribution, the municipality had promised to buy 10 city buses, 11 garbage trucks and about 30 cars. In addition, the towns of Umeå, Luleå, Örsköldsvik, Piteå, Boden and Skellefteå in the region of Norrland began to explore the potential for a regional biogas network, Biogas Nord, similar to that in the west of Sweden (Samuelsson, 2005d).

In addition to the large waste management companies and sewage treatment installations, individual agrarians started to produce biogas from manure. Sometimes other waste materials were included as well, such as crops, food and abattoir waste. The amount of biogas produced was small and the government did not grant subsidies for these projects. One of the main incentives was the bio-fertilizer by-product, which has also stimulated farmer cooperation in larger scale digestion installations (Held et al., 2008). This development indicates a growing demand for and the potential for economic gain from producing biogas.

Table 34 summarizes the main biogas clusters and production facilities described in the text, which are only a selection of the many upgrading plants producing bio-based vehicle gas in Sweden. There are also several plants producing biogas for electricity and/or heat production. Table 34 shows the development of the various experiments and clusters as well as the main technologies used. Regarding technology development, there is a shift from one feedstock, sewage sludge, to several, including foods in a co-digestion process. One interesting development is that the new digester in Boden uses a high temperature, thermofile, digestion process, which is different to all the other processes focused on low temperature, mesofile, digestion. All the actors are municipalities or municipally owned companies. Finally, all the projects have been awarded government funds. Due to limited data, some funds are likely to be missing in Table 34. Apart from the small scale farmer plants that received no funds, the table shows large scale government funds, which makes it likely that funding is important for realizing large scale biogas production.

Alongside the collaboration within regional clusters in Sweden, there was collaboration across regions at the European level. Unlike the many EU funding programmes that aid renewable fuels or environmental vehicles, Biogasmax – which started in 2006 – was designed just for biogas. It aimed to reduce pollution and improve waste management in urban areas by facilitating the development of production facilities for biogas vehicle fuel, related infrastructure and use. The city of Lille in France coordinated the programme. The Swedish programme participants were the cities of Stockholm and Gothenburg, Svensk Biogas in Linköping, Environmental vehicles Stockholm and Biogas Väst (Biogas Väst, 2008; Norrman, Belhaj, Arnell, & Flodström, 2005b). Some of the goals in Stockholm were to open new filling stations, increase production, and continue to stimulate the purchase of biogas cars by means of local incentives such as free parking and information campaigns. Biogasmax was expected to end in 2010 (Norrman et al., 2005b).

Of all the biogas clusters developed in this period, the Biogas Väst cluster was the most successful and seen as a role model. The leading position of Biogas Väst was also visible in its vision to become a leading European partner in the field of biogas propulsion and vehicle implementation, by having 100 000 biogas vehicles running by 2020 (Biogas Väst, 2008).

Already in 2008, its goal to receive increased international recognition was well under way when Biogas Väst won a US environmental prize, 'The Blue Sky Award', presented by the non-profit organization, Calstart, based in California (Biogas Väst, 2008). In addition, to achieve its ambitions Biogas Väst had expanded its activities to support advanced gas fuels and R&D activities. Its own report (Biogas Väst, 2008) describes western Sweden as being at the forefront in the field of waste research through advances made at the Waste Refinery Competence centre. Moreover, through developments at Göteborg Engergi's research facilities and Chalmers University of Technology, the region was argued to have a leading position with regard to R&D in the field of gasification research for the production of bio-SNG (Biogas Väst, 2008). Another recent path of development was the growing interest in liquid biogas. In 2008, BRG and Biogas Väst received KLIMP funding of SEK 83 million in grants for local climate investment, to develop a production facility for liquid biogas, the expansion of infrastructure, the conversion of heavy vehicles to run on liquid gas and information initiatives by 2012. The total investment for the two projects is SEK 342 million, implying not only government investment, but also local investment from industry. The expectations were that the liquid gas project would lead to a reduction of 56 000 tonnes of greenhouse gas emissions per year (Biogas Väst, 2008).

Name/ location	Start	Technology	Feedstock	Capacity	Invest-ment	Funds
Biogas Väst start 2001 (Västergötland county)						
Gothenburg						
Ryaverket, Gryaab sewage	1992	Mesofile, upgrading: PSA	Sewage sludge	60 000 MWh	128 MSEK	
	1996	Mesofile co-digestion	Sewage sludge, fats			600 000 SEK
Scale-up upgrading Arendal	2007	Mesofile co-digestion, upgrading: Cooab				KLIMP 9 MSEK
Biogas Öst, 2008 (Uppsala, Stockholm, Västmanland, Södermanland, Örebro, Östergötland and Gotland counties)						
Linköping						
Tekniska verken sewage	1992	Mesofile, upgrading: PSA	Sewage sludge	65 000 MWh, 45 000 ton bio fertilizer	130 MSEK	LIP and KLIMP 17 MSEK
Åby plant, upgrading	1997	Mesofile co-digestion, upgrading: water scrubber	Food, manure			
Åby scale up	2002					
Norrköping, Händelö	1997		Wastewater wheat ethanol plant			
Stockholm						
Bromma sewage	1996-2000	Mesofile	sewage sludge	Pilot	35 MSEK	LIP 27 MSEK
Bromma scale up	2000-	Mesofile, PSA upgrading		19 000 MWh		
Hendriksdal sewage	2003-	Mesofile, co-digestion, water scrubber upgrading	85% sewage sludge 15% fats and food	58 000 MWh	99 MSEK	
Biogas Syd, 2005 (Skåne county)						
Kristianstad						
Kristianstad Local sewage plant / Karpalund,	1999	Mesofile co-digestion, water scrubber upgrading	Manure, food waste	59 300 MWh and 63 000 ton fertilizer	107 MSEK	LIP and KLIMP 9 MSEK
Scale-up upgrading	2007					
Helsingborg						
Helsingborg, NSR	1997	Mesofile, upgrading: PSA and water scrubber	Sewage sludge	12 000 MWh, 44 000 tonnes fertilizer	120 MSEK	KLIMP 19 MSEK
Biogas Nord, planning stage (Norrland county)						
Boden						
Boden	2007	Thermofile co-digestion, water scrubber upgrading	Sewage sludge, food	400 MWh and heat	46,3 MSEK	LIP, KLIMP 18,7 MSEK

Table 34: Selection of biogas production and upgrading sites, 1992-2008
Source: Adapted from Held et al. (2008)

8.2.2. Biogas SNM analysis, 1998-2010

Gas													
Year	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Biogas networks				Biogas Väst									
								Biogas Syd					
									Biogas Max				
											Biogas Öst		
Biogas upgrading	8				10	13				17			
Natural/biogas pumps	19	22	26	31	39	48	65	85	97	115	122	134	167
Natural/biogas light vehicles	759	1008	1292	1479	2712	3575	4519	6965	11024	13407	15642	21749	30105
	Volvo bi-fuel			additional brands									
Heavy vehicles	55	84	103	121	178	191	225	276	338	369	397	412	499
Buses	265	282	330	400	419	482	554	656	757	760	849	963	1434
Total vehicles	1079	1374	1725	2000	3309	4248	5298	7897	12119	14536	16888	23124	32038

Table 35: Biogas development, 1998-2010

Network actors	**Biofuel**	**Expectations**	**Key experiments**	**Learning**	**Socio-technical configurations**
municipalities, their wastewater/biogas plants, fleets and private market, vehicle suppliers, natural gas suppliers	Biogas pure use and production	Expectation of biogas as the most environmental fuel increases and local benefits of improving waste management and contribute to regional development.	Expansion of use in heavy vehicles, but also in private bi-fuel vehicles. West Sweden particularly successful.	Technical, economic and institutional lessons proceed as a result of collaboration with natural gas actors. Stockholm example indicates problem adapting lessons across regions.	Biogas is the most popular fuel in heavy vehicles. Also private bi-fuel cars and use in fleets show expanding market niche with related infrastructure in collaboration with natural gas actors. This indicates increased niche stability. Nevertheless, technical problems in Stockholm region have hampered niche expansion.

In this period the biogas network was still made up of municipal biogas producers and fleets. These increasingly formed regional development clusters, of which Biogas Väst was a forerunner that managed to create highly profitable collaborations with regime actors such as vehicle producers and natural gas suppliers. An example of this profitable collaboration was the green gas principle, which meant that biogas actors could take advantage of existing natural gas infrastructure, pipelines and distribution locations. Another example were the biogas distribution goals set by big natural gas distribution companies. Such collaboration, however, was not possible in all biogas clusters since natural gas infrastructure was only available on the west coast. In addition to regime actor support, national incentives such as the general tax exemption for biogas, increased subsidies for biogas vehicles and local investment programmes (LIP, KLIMP) stimulated municipalities in the set up of regional biogas clusters. The result was a larger and stronger biogas network that at the end of the period indicated increasingly more aligned activities.

The network development pattern was reflected in the change in *expectations* of natural gas actors as a potential barrier for biogas development to a means for biogas development. The expectation that biogas would increase environmental benefits, and contribute to local waste management and regional development remained in this period, driving municipal initiatives further. The lesson that biogas was the most environmentally beneficial biofuel reinforced these expectations. In addition, the success stories of the Gothenburg trial stimulated a greater involvement of actors and experiments in other regions, which in turn led to increasingly shared expectations. However, biogas implementation in the Stockholm region was not as successful. It failed to meet the greatly expanding market demand because it did not pay sufficient attention to local social, economic and technical conditions. This had a slightly negative impact on generally very positive biogas expectations.

While the negative experience in Stockholm is likely to have slowed down the niche expansion in the late 2000s, the general development pattern was positive, with four regional clusters producing and using biogas in Sweden by the end of the period (see Table 35). Biogas use expanded consistently and surpassed natural gas use in 2006 (see Table 33). Biogas had the smallest market share of all biofuels. However, when looking at the use of both natural and biogas, they were the leading alternative fuel for heavy vehicles (Table 33). Ethanol had previously dominated the alternative fuel niche for heavy vehicles.

8.2.3. Biogas discourse development, 1998-2010

Unlike other biofuels, biogas already had a general tax exemption as a result of the Swedish government's negotiations with the EU in 1995. Hence, biogas did not become a victim of the discontinuance of tax exemptions for a variety of biofuel experiments in 1999-2003. However, many municipalities with biogas projects continued to lobby to prevent the EU from changing its mind with regard to the extraordinary biogas tax exemption (Miljörapporten, 1998b). The fact that biogas was not questioned in this period is likely to be related to the embedding of the discourse in the general environmental discourse, as shown by the conclusion by the Alternative Fuel Committee (1996) in the previous period that biogas was the most environmentally benign fuel. The only criticism of biogas was the limitation on suitable and affordable feedstock to provide for a larger part of the vehicle market. Hence, like RME, biogas was seen only as a potential niche fuel (Kommunikationskommittén, 1997; Hådell, 2001).

As is outlined in the ethanol section, the increased popularity of biogas and additional proof of the embedding of the fuel in the environmental discourse is reflected in the LIP and KLIMP programmes granting funding from 1998 to 2008. The LIP's goals included furthering both environmental sustainability and local employment while the KLIMP Programme was increasingly geared to greenhouse gas reductions. The majority of both the LIP and the KLIMP funds for the transport sector went to biogas vehicles, production and distribution technology (Rehnlund et al., 2004; Naturvårdsverket, 2011b). For instance, the KLIMP spent about 30% of its total programme funds on biogas for energy and transport. This was particularly large given that all types of climate friendly projects for local development could apply for KLIMP funds (Naturvårdsverket, 2011a). A contributory factor to the popularity of biogas was the fact that municipalities were the only ones eligible to apply for funding from these programmes, while other actors could only provide matching funds. Unlike other alternative fuels, biogas matched the areas of responsibility that municipalities had to deal with –waste management, environmental policy goals and regional development.

In addition, the biogas coalition was strengthened by the development of a cluster of biogas promoters in the west of Sweden interested in expanding the biogas and natural gas vehicle market. The initiative was initially triggered by an investigation into the possibility of creating a national biogas cluster in 1998. Gothenburg City and Volvo showed an early interest. Together with local biogas actors at the municipal and regional levels, the Swedish Road Administration, the LRF and local companies, they formed a regional biogas development cluster in 2001: Biogas Väst. The project promoted biogas development, but it also contributed to the stabilization of the biogas discourse by presenting biogas as a means for both regional economic and environmental development, thereby increasing the embedding of biogas in these general discourses (Norrman et al., 2005a).

In the late 1990s, considerable government support was given to further the implementation of the technology, which can be linked to the growing lobby for environmental vehicles in general and biogas in particular. One example was subsidies for environmental vehicles, in particular gas vehicles. A bottleneck to further biogas expansion identified in the previous period was the high cost of gas vehicles (Månsson, 1998). This was partly due to the lack of economies of scale, but also because the tax on vehicles was based on the price of the vehicle. Since environmental vehicles were generally more expensive than conventional vehicles, and gas vehicles in particular, they became even more expensive due to the higher tax. Thus, to stimulate gas vehicles and other environmental vehicles, the government lowered the fringe benefit tax for alternative fuel vehicles that applied to leased and company cars, to the level of their conventional vehicle counterparts in 2000 (Statsrådsberedningen, 1999; Persson & Ringholm, 1999). Additional tax relief was given to selected alternative fuel company and leasing vehicles, such as gas and ethanol, which only had to pay 80% of the amount of their fossil fuelled counterparts from 2002 until 2006 (Persson & Nuder, 2005). As a result of these tax benefits, there was a large increase in gas vehicles sales and gas fuel pumps in the west of Sweden in 2002 (Miljörapporten, 2003e). According to Ahlbäck (2003), particularly strong lobbying by the biogas cluster on the west coast, including Fordonsgas Väst, Volvo, Göteborg Energi AB, Göteborg Transport Office and Business Region Göteborg under the name TRUST (big city transportation development), contributed to the tax relief for biogas vehicles.

These positive biogas developments, coupled with consistently increasing demand for biofuel vehicles in general as a response to the preparation of the EU Biofuel directive, led the natural gas coalition to show increasing interest in collaborating with the biogas actors and expanding its role in the biogas propulsion sector. This was first reflected in a return to the debate on expanding Sweden's natural gas pipeline in 2003, which the natural gas actors argued would not only aid the energy and heat sector, but also further the development of biogas by enlarging the pipeline infrastructure (Ringström, 2003a). That the natural gas actors were serious about assisting biogas expansion by exploitation of the natural gas infrastructure was shown in the setting up of the 'green gas principle' in the west of Sweden (Ahlbäck, 2003).[88] Second, in collaboration with biogas actors, natural gas companies started making large investments in bio-based vehicle gas in 2003, in addition to conventional fossil gas. Moreover, they promoted biogas as the most environmentally friendly fuel and thus the fuel for the future. Large natural gas actors set particular goals for biogas production and distribution pumps for 2008. For example, the biggest natural gas actor, with 30% of the market, Sydkraft, promised to increase its share of vehicle biogas distribution from 15% to 50 % (Samuelsson, 2004c; Samuelsson, 2007h). Compared to other alternative fuels, private investment in the gas sector was particularly impressive.

While natural gas could be seen as a competitor for biogas actors, Ringström (2003b) points out that many actors, especially the biogas producers, were generally positive about such collaborations: 'Many biogas producers see the expansion potential that the natural gas pipelines imply as positive' (ibid., translation by the author). This was because the pipeline infrastructure could be used for both natural gas and biogas. Only LRF was more hesitant about the intentions of the natural gas companies (Ringström, 2003b). However, Mattiasson, CEO of the Swedish Gas Association (Svenska Gasföreningen), disagreed with Ringström. According to Mattiasson, the biogas coalition worried about a takeover of the biogas market if the natural gas actors expanded the pipeline. Put in perspective, these worries were reduced compared to the 1980s and early 1990s, since the economic potential of biogas had become more realistic with the increased strength of the biogas discourse (Westergård, 2006a).

As in the previous period, the most critical lobby against natural gas expansion was the ethanol coalition. It argued that cheaper natural gas would take over the biofuel market once the pipelines were in place (Samuelsson, 2004b). One example is the quote by the main ethanol proponent, Per Carstedt.

> I support biogas as a vehicle fuel, not natural gas. The problem is that biogas is a niche fuel […]. If a gas were used to reorganize transport in society, that gas would be natural gas. And to go from gasoline and diesel to natural gas is to go from ashes to fire. (Carstedt in Samuelsson, 2004h, translation by the author)

Carstedt's support for biogas was similar to the ethanol lobby's support for both RME and methanol outlined above, and thus may reflect the strategy of the ethanol coalition to construct a common biofuel discourse to gain more political power. Despite Carstedt's arguments for biogas, the quote also makes clear that ethanol was to be preferred over biogas by stressing the limits of biogas as only a niche fuel.

In addition to the potential benefits of collaborating with the natural gas industry, biogas seemed to benefit from the development of the biofuel discourse, even though biogas was not actively part of this discourse. One example is the argument that first-generation fuels were a bridging technology outlined in the ethanol section. This argument was put forward by the emerging biofuel discourse as the main strategy to reach the EU's targets for 2005 and 2010 in the report of the Commission on Renewable Vehicle Fuels (Sandebring, 2004). Biogas was not part of this lobby, but given that biogas is a biofuel and the great support given to biogas by LIP and KLIMP, among other subsidy schemes, benefits from the biofuel discourse are likely. In addition to the bridging argument, the idea of introducing a 'green' certification system,

[88] The principle meant that any natural gas sold as vehicle fuel was compensated for by an equal amount of biogas used in another sector (Ahlbäck, 2003).

proposed by Commission on Renewable Vehicle Fuels (Sandebring, 2004), was seen as particularly beneficial for biogas since it was classified as the most environmentally beneficial fuel. In this way, the benefits of a certification system were seen to make the expense of the technology less of a development barrier. Consequently, biogas supporters lobbied for the implementation of a certification system (Samuelsson, 2007e). However, certification was not foreign to other biofuel actors, such as Sekab outlined in the ethanol case above.

A variety of local incentives also emerged as part of a broader biofuel, or environmental vehicle, discourse from which the biogas discourse benefitted. Examples include free parking in major cities, which started in Gothenburg in 2003 and in Stockholm in 2005, and exemption from the congestion charge in Stockholm from 2006 (Ahlbäck, 2003; Birath & Pädam, 2010; Samuelsson, 2004g).

However, not all the measures suggested to achieve the EU biofuel targets were considered beneficial by the biogas coalition. In particular, the suggestion by the Environmental Party to oblige oil companies to set up alternative fuel pumps was of great concern to both the natural gas and the biogas coalitions. According to Rietz, the CEO for the Swedish Gas Technical Centre (SGC), 'this law is the final straw for gas vehicles'. Ethanol would be given a head start, while other alternative fuels such as gas would be disadvantaged (Lindemalm, 2004a, translation by the author). Nordin at the branch organization for Swedish oil distribution companies, the Swedish Petrolium Institute (SPI), shared the opinion of Rietz and took the argument further by stating: 'This law means that there will be E85 at the stations. One gas pump costs 10 times as much as an ethanol pump. The consequence of pushing through this legal requirement is that biogas dies overnight' (Lindholm, 2005, translation by the author).

Despite the fierce criticism of the pump law by biogas promoters and low blend promoters, the Environmental Party continued to promote it. According to Domej at the Environmental Party 'The demand for biogas was already bigger than the supply [...]', and thus the pump law would not harm biogas expansion (Lindemalm, 2004a, translation by the author). Quite interestingly, there was not a strong lobby of biofuel actors defending this law. As is indicated in the ethanol section, not even the ethanol coalition was very enthusiastic about it, although they were the ones to profit from it. According to Lindemalm (2004a), the outcome of the law was mainly dependent on high-level party politics, in particular the collaboration between the Environmental Party and the governing party – the Social Democrats.

Meanwhile, the government announced the Budget bill for 2006 (Persson & Nuder, 2005). The bill prescribed that the fringe benefits tax for gas cars should be reduced. Instead of the current 80% of the taxable value of a conventional vehicle, the tax was reduced to 60% for gas vehicles while ethanol vehicles were still taxed at 80%.[89] The explanation in the bill was that gas vehicles were particularly expensive and had higher environmental benefits making them more similar to EVs than ethanol vehicles, and should therefore have the same benefits as EVs, which currently only paid 60% tax. According to Samuelsson (2005c), the real reason behind this bill was to compensate for the obligatory pump law that was soon to be implemented, that is, to stimulate the sale of gas vehicles in order to limit the competitive advantage of ethanol once the pump-law was implemented.

A slightly revised pump law was presented in a government bill (Persson & Sommestad, 2005) one month after the budget bill. As is outlined in the ethanol section, this bill was agreed by parliament and placed obligations on larger filling stations at the initial stage and small stations in the future, with an implementation period of 2006–2010. That the pump

[89] However, the maximum reduction cannot exceed SEK 16 000 annually (Persson & Nuder, 2005)

law would benefit ethanol due to the relatively cheaper technology and installation costs compared to gas was acknowledged by the government. Consequently, the government complemented the law with the promise of a subsidy for constructing gas pumps equal to SEK 150 million in 2006 and 2007 (Westergård, 2006a). In 2008, this subsidy was prolonged to the end of 2009. The total number of gas pumps subsidized through this scheme was 105, and the total amount of subsidy granted was SEK 114 million (Naturvårdsverket, 2012).

As is outlined in the ethanol section, criticism of conventional biofuel emerged in the late 1990s and increased throughout the 2000s, from first a synthetic biofuel coalition and later an anti-biofuel coalition (ibid.). Unlike other first-generation fuels, such as conventional ethanol and RME, biogas was seen as a more environmentally benign fuel. However, the limited ability to extend biogas production meant that biogas was seen as a niche fuel, making it inferior to synthetic fuel alternatives (Hådell, 2001). As a result of the limitations on biogas as a fuel option, the biogas and natural gas coalition presented their own bridging scenario, from biogas/natural gas to synthetic biogas. First generation natural gas/biogas would prepare the infrastructure (pipelines and distribution) and the vehicle pool for a future synthetic gas fuel. As an argument against the proponents of synfuel, i.e. methanol, FT-diesel and DME, the coalition also argued that the use of synthetic gas, without further waste of energy for refinement to diesel fuels, was more energy efficient and more environmentally friendly (Westergård, 2006a; Bengtsson, 2007). There has been no visible evidence that the synthetic gas coalition responded to this bridging argument or critique.

The biogas coalition furthered this reasoning by arguing that biogas production could be increased until synthetic gas was sufficiently mature, using energy crops in addition to the waste resources available (Westergård, 2006a; Bengtsson, 2007). While previous research showed that crop-based biogas was not as efficient as the use of waste (Samuelsson, 2004b), more recent findings showed that co-digestion of waste and crops increased biogas output (Westergård, 2006a). Both the bridging argument and the promise of co-digestion were means to answer the criticism that biogas was only a niche fuel. According to Westergård (2006b), great plans were made for synthetic gas production, and some biogas actors hoped to be able to skip natural gas use totally by going from biogas directly to synthetic gas.

With the emerging anti-biofuel lobby, critical of crop-based biofuel production for competing with food production, increasing CO_2 production, harming biodiversity and the local population in the South, the argument for crop-based biogas production is likely to have become less attractive. However, some (see: Samuelsson, 2007h) argue that the anti-biofuel sentiments stimulated the development of biogas (ibid.). This is likely to be based on the fact that biogas was generally produced locally, based on waste not crops and considered very environmentally friendly. In fact, despite the problems with introducing biogas to the Stockholm region, Westergård (2006a) indicates that biogas hype was building in the mid-2000s.

With regard to the potential threat from the natural gas industry, the collaboration between the biogas and natural gas actors had been quite beneficial for biogas thus far. According to Anders Mathiasson, CEO at the Swedish Gas Association, the biggest gas company, Eon, previously Sydkraft, kept its word to increase the share of biogas in the vehicle gas sold. For Eon, the biogas share was 15% in 2003 and 50% in 2007. Due to the continuing popularity of biogas, the large natural gas companies set new goals. The number of gas filling stations was to be doubled from 100 to 200 before 2010 and production was to be increased accordingly. Investors to meet this goal were both municipalities and the large natural gas companies. However, there was still some reluctance with regard to the expansion of the natural gas pipelines. Mathiasson recommended an agreement to ensure that a certain percentage of the gas transported through the pipelines would be biogas (Westergård, 2006a).

8.2.4. Biogas discourse analysis, 1998-2010

Policy	Level	Year	Type	Size SEK	Explanation
Tax exemption	Government	1995-	Regulation		Only biogas with general tax exemptions from 1995
LIP	Government, Municipality	1997-2002	Subsidy	SEK 150 million government + 600 MSEK matching	Local Investment Programme (LIP), which alternative fuel funds mainly supported biogas.
KLIMP	Government, Municipality	2003-2008	Subsidy	SEK 622 million government + 2640 matching	Climate Investment Programme (KLIMP), the alternative fuel funds of which supported biogas.
Subsidy gas pumps	Government, municipalities, industry	2006-2008	Subsidy	SEK 114 million	105 gas pumps sponsored by subsidy scheme
Regional clusters	Municipality, industry	2001	Field trials, infor-mation exchange		Various local clusters, such as Biogas Väst, supported local biogas production and use through local incentives, fundraising, and information.
Biogas Väst: Gothenburg	Municipality	1992-2008	Production	SEK 128 million total. SEK 9.6 million. mainly KLIMP	Production plant and upgrading
Biogas Öst: Linköping, Norrköping	Municipality	1992-2008	Production	SEK 130 million total. KLIMP SEK 17 million	Production plant and upgrading
Stockholm	Municipality	1996-2008	Production	SEK 114 million total. LIP SEK 27 million	Production plant and upgrading
Biogas Syd: Kristianstad	Municipality	1999-2008	Production	SEK 107 million total. LIP/KLIMP SEK 9 million.	Production plant and upgrading
Helsingborg	Municipality	1997-	Production	SEK 120 million total. KLIMP SEK 19 million.	Upgrading
Biogas Nord: Boden	Municipality	2007-	Production	SEK 46.3 million total. LIP/KLIMP SEK 18.7 million	Production plant and upgrading
bi-fuel vehicles	Municipality, industry	1998-2008	Field trial, market creation		Personal vehicles increased from 759 to 15642. Stimulated by government leased vehicle subsidy, local incentives
Buses and trucks	Municipality, industry	1998-2008	Field trial, market creation		Heavy vehicles increased from 320 to 1246

Table 36: Biogas policy developments 1997-2010

Biofuel	Discourse	Mobilization/ impact of wider discourses, events and policies	Discourse coalition	Target audience	Key activities, strategies	Resulting space/ policy creation or disruption
Biogas production and pure use.	Biogas as most environmental biofuel that could aid local economic development and waste management	Embedding in local and global environ-mental discourse and regional development discourse.	Local public authorities, their waste managers increasingly organized in regional clusters (e.g. Biogas Väst). In late 2000s, increasing support from natural gas discourse.	Lobbying took place in the media, the political arena, scientific reports, and campaigns. The strategies were presenting positive experiences and keeping friendly relations with other discourses to take advantage of their development.	Lobbying was directed towards the govern-ment and wider audience to accept higher prices for the more expensive biofuel.	Benefit from natural gas and biofuel discourse develop-ments, increased subsidies for vehicles at the local and national levels and continued general tax exemptions.

Biogas was ranked as the best biofuel alternative in the late 1990s due to its high CO_2 emission reductions. As in the previous period, it was also thought to contribute to regional economic development, reduced unemployment and the remedy for local emissions and waste management. In the 2000s, new elements of the discourse were the increased acceptance of natural gas as a bridging technology for biogas instead of a competitor, and biogas as a potential bridging technology to syngas in vehicles. The embedding of biogas into the general environmental discourse increased in this period as a result of it being ranked as the most environmentally friendly biofuel. In comparison with other biofuels, biogas also enjoyed particularly deep embedding in the regional development discourse, as indicated by its great popularity among municipalities. In addition, biogas gained embedding in the biofuel discourse which grew with the publication of the EU Biofuel directive.

As in the previous period, local municipalities and municipally owned companies such as waste managers led the biogas coalition. However, the previously lead by Linköping municipality was taken over by a cluster of municipalities around Gothenburg – Biogas Väst. An additional change was that the natural gas actors increasingly lobbied for biogas by presenting natural gas as a bridging technology through measures such as the 'green gas principle'. The lobbying activities carried out made use of the media, mainly local but also national political arenas, and reports, scientific publications and various information dissemination and campaigning activities to gain increased support from national and local authorities, industry and the general public. One strategy was to use the positive example of Biogas Väst as a role model to take attention away from problems elsewhere. Another strategy was continuing friendly and diplomatic relations with both natural gas and biofuel actors in order to gain the most from both discourses. An example of this was the reaction to the expansion of the natural gas pipeline, which ethanol actors met with strong resistance, arguing that it would harm biogas expansion, while biogas actors kept a low profile seeing both potential benefits and problems. A strategy to avoid criticism of being a niche fuel and from the anti-biofuel discourse was to position natural gas and biogas as bridges to an advanced future synthetic gas fuel. However, this was neither picked up nor challenged by syngas actors.

While the biogas discourse managed to avoid the harsh criticism from the synfuel and anti-biofuel discourse due to its high CO_2 emission reductions, the argument that biogas was a niche only remained a negative factor. Nonetheless, unlike other biofuels, the general biogas tax exemption could not be questioned as easily. The government gave additional support in the form of national subsidies for regional development (LIP and KLIMP), refuelling infrastructure, vehicles and production facilities, as well as a variety of local incentives and regime protection for natural gas actors. The fact that biogas could only be used as a pure fuel and depended on decentralized fuel production required high visibility and commitment from local communities and thus a relatively high degree of institutionalization in comparison with other biofuels.

8.3. BIODIESEL BECOMES A LEGITIMATE LOW BLEND FUEL, 1998-2010

This section describes the development of biodiesel. Unlike chapter 7, this chapter presents both niche and policy processes. First, I describe the development of the biodiesel niche in the period 1998-2010 followed by an SNM analysis. Second, I describe the political processes leading up to biodiesel policy over a longer period but with a focus on the period 1998-2010, followed by a discourse analysis.

8.3.1. Biodiesel niche development, 1998-2010

At the end of the previous period, positive RME expectations increased in relation to RME low blends in diesel. This was, among other things, due to the Alternative Fuel Commission's (Alternativbränsleutredningen, 1996) recommendation of large scale implementation of low blend RME. These positive expectations triggered oil distribution companies such as Preem to start including a 2% RME fuel mix in its diesel under the name Biomil.

Despite positive expectations, negative evaluations of pure RME use continued. One example was the report by Motortestcenter in 1997, which showed lower CO_2 emissions but higher emissions of health damaging nitrogen compared to the commonly used environmental class 1 fossil diesel. As a result, many environmentally conscious municipalities, taxi companies and delivery firms that were promoting RME or running trials withdrew from their projects (Miljörapporten, 1997a). Preem also paused its Biomil project despite the fact that the negative reporting primarily focused on pure RME and not on RME blends. One year later Preem introduced the 2% RME blend, but only in six filling stations in the north of Sweden. Preem cooperated with the farmers' organization Lantmännen in organizing an elaborate evaluation of the Biomil fuel, which was positive. Contrary to the negative results of the many tests with pure RME, the low blend had the same environmental and technical benefits as the cleanest diesel used – environmental class 1 diesel (Miljörapporten, 1998d).

In line with the Alternative Fuel Commission's advice to support RME low blends (Alternativbränsleutredningen, 1996), government bills proposing increased support by granting general tax exemptions on all biofuels, RME included, were voted through parliament (Persson & Åsbrink, 1997; Peterson & Lindh, 1998). While waiting for the execution of these decisions, no tax exemptions were granted for new RME projects set up (Riksrevisionen, 2011). However, the promise of a general tax exemption increased RME expectations. Many engine and car developers were also positive about the environmental benefits that low blend RME in diesel implied (Miljörapporten, 1999a). As a result, several actors, such as the RME importer Fred Holmberg & Co and the RME producer Svenskt Ecobränsle, applied for tax exemptions from the Ministry of Finance (Miljörapporten, 1999a; Miljörapporten, 1999b).

However, in 1999 the tax exemption was not granted as promised for either RME or the majority of ethanol applicants. The Ministry of Finance based its decision on scientific studies showing that the environmental gains from fuels like ethanol and RME were uncertain (Miljörapporten, 1999b). This had devastating consequences. For instance, the company Svenskt Ecobränsle had to close its factory in 1998 and lay off all its employers. Other victims were the farmers who had started cultivating rapeseed for which there was now no market (Miljörapporten, 1999a) (Ecobränsle, 2012).

The negative reports on RME emissions meant problems gaining continued support from both national authorities and local authorities. Vehicles running on pure RME, which were benefitting from so-called clean vehicle subsidy programmes in the three largest cities, Stockholm, Gothenburg and Malmö, were excluded from the clean vehicle definition and thus also from support (Sandén & Jonasson, 2005).

In 2002, the bulk of the tax exemptions granted for RME and ethanol were due to expire. To avoid a steep increase in price for alternative fuels, the Ministry of Finance changed its mind and agreed to renew the tax exemption. This meant that the companies that had a tax exemption for a predefined amount of fuel in 2001 got the right to claim the same amount of tax exemption in 2002 (Miljörapporten, 2001c). Later in 2002 it was announced that the EU Biofuel Directive, setting targets for biofuel implementation, would be published in 2003. Consequently, the tax exemption was prolonged for an additional year as a bridge to the planned tax reform in 2004 (Miljörapporten, 2003c). The tax reform, outlined in the government budget bill for 2004, meant that all CO_2 neutral fuels, including RME, were exempted from both CO_2 and energy tax for a period of five years starting in 2004. The only tax on biofuels was VAT (Persson & Ringholm, 2003). An additional change that is likely to have been triggered by the preparations and implementation of the Biofuel Directive was the creation of a European CEN standard EN 14214 for biodiesel. In 2003, this European standard superseded the Swedish RME standard WW 155436 set in 1996 (Rehnlund & Van Walwijk, 2005)

The termination of tax exemptions in 1997 and the decision not to give the promised general tax exemption in 1999, and also the discontinuance of support by local authorities at the turn of the century, had a severe impact on RME use. Table 37 shows a severe dip in RME use in 2000–2001. In 2002, however, sales slowly increased and there was a more drastic increase after 2006. The decision to extend existing exemptions in 2002 and the general tax exemption in 2004 are likely to have contributed to this increase.

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Low blend biodiesel					3.9	4.8	8.6	9.0	55.8	125	160	194	207
Other biodiesel	6.2	7.3	2.8	0.7	0.7	0.6	0.7	1.6	9.3	5.1	4.8	12	18
Total	6.2	7.3	2.8	0.7	4.6	5.4	9.3	10.6	65.1	130.1	164.8	206	225

Table 37: Biodiesel consumption measured in 1000m^3, 1998-2010
Source: Statistics Sweden

Table 37 also shows that low blend biodiesel use, of which the great majority was RME according to the Swedish Energy Authority (Statens energimyndighet, 2011), gained in popularity during this period. This could be related to reports promoting low blend use. One example was the publication by the Commission on Renewable Vehicle Fuels (Sandebring, 2004), which stated that a biofuel mix in conventional fuels, and thus also RME in diesel, was a good means to reach the targets set out in the Biofuel Directive. Moreover, according to this Commission, the current standard allowing a 2% RME blend in diesel should be raised to 5% to reach the targets for 2010 (ibid.).

Year	2003	2004	2005	2006	2007	2008	2009	2010
Number of pumps	0	0	23	17	16	13	17	25

Table 38: Number of public RME filling stations, 2003-2010.
Source: Swedish Petrolium and Biofuel Institute

Table 37 also indicates other RME use, which is likely to refer to various higher blends and pure use. This use drops heavily in the years 2000-2001 and has an irregular development from 2005 to 2010. The drop in 2000 and 2001 and low consumption thereafter is most probably related to the withdrawal of national tax exemptions and local incentives as outlined above. Table 38 shows that there were no public refuelling stations between 2003-2005, indicating that the consumption of pure RME was low in this period. However, data presented for the previous period indicate that distribution of pure RME was carried out in 1996-1997. Distribution activities may have been temporarily halted after 1997 due to the end of the tax exemption. Like Table 37, Table 38 shows an increase and irregular development after 2005. This may be related to high feedstock prices restricting market expansion, as is outlined below. While the development is ad hoc, the overall trend is an increase in high blend and pure RME use from 2005, which can be explained by the financial stimulus from the general biofuel tax exemptions and the so-called pump law. As is outlined in the government bill (Persson & Messing, 2006) and the ethanol section above, the pump law was an obligation to distribute biofuel at filling stations, whereby targets for biofuel pumps were set out for various sizes of filling stations from April 2006 to March 2009.

Like the previous period, hardly any material can be found on higher blend and pure RME initiatives. However, according to Eriksson and Rehnlund (2008), only certain heavy vehicles, such as Scania, that can converted to 100% RME use. Previously, certain light vehicle models allowed RME use, but this had changed over the years. This is partly related to the type of particle filters used in modern light and some heavy vehicles, which are not compatible with RME use. Consequently, the experiments run with pure RME were carried out with heavy vehicle fleet operators. Many of these were in the agrarian sector and tied to the production of RME.

Unlike pure RME use, the tremendous increase in RME in low blend use in this period is relatively well documented. According to Ecobränsle (2012), the first experiments with a 2% blend in diesel were introduced in 1996. However, implementation by fuel distribution companies seemed to start in 1998, as is outlined in the case of Preem above. In parallel with the introduction of RME in diesel by Preem (Sandebring, 2004), OK/Q8 started to mix 2% RME in a limited amount of its diesel. Many fuel distributors expressed an ambition to expand the low blend RME niche, but contemporary tax regulations made the sale of low blend RME in diesel unprofitable. The problem was that the 2% RME mix changed the temperature of the diesel so much that it did longer fitted the standard for environmental class 1 diesel (Miljöklass 1 diesel), but a lower environmental quality standard – class 3 diesel. A class 3 diesel meant higher taxes, and thus higher costs. The difference in tax for the two diesel classes was SEK 240 per m^3, and in the case of OK/Q8 this tax difference was SEK 140 million for the total amount of diesel sold (Ringström, 2005b). As a result, the oil trade association Swedish Petrolium Institute (SPI), the trade association for vehicle manufacturers and importers, Bilsweden, and the farmers' organizations, LRF and Lantmännen, sent in a complaint to the Ministry of Environment in August 2004. In addition, they demanded the government adjust the Environmental Class 1 Diesel standard to allow a 5% use instead of 2% RME in diesel, and to avoid this becoming mixed up with Environmental Class 2 Diesel (Samuelsson, 2004d).

The Road Administration developed a legislative proposal for a 5% blend in diesel in 2005. In the wake of this proposal, actors saw increased opportunities for RME production (Ringström, 2005c). The first domestic production plant, started by Svensk Ecobränsle in 1996, was closed in 1998 (Ecobränsle, 2012). A potential explanation for this was the inability to gain new tax exemptions from the government. However, according to Blomquist (2006), one of the leaders of the company had kept a private farm-based pilot plant going with 10 000 to 15 000 tonnes of annual production. Hence, there was sufficient experience. According to Ringström (2005c), Lantmännen, the owners of Ecobränsle, the current name of Svensk Ecobränsle, made preparations to build an RME factory in an old dairy factory in Karlshamn. Lantmännen were to invest SEK 33 million in the factory and asked Svensk Ecobränsle to run it (Ringström, 2005c). Although the initial production of the plant would be 40 000 tonnes annually, the capacity was 100 000 tonnes (Ringström, 2005c; Blomquist, 2006). This was due to the limited rapeseed cultivation area. The 40 000 tonnes RME required 37 500 ha of autumn rapeseed, which was the total Swedish autumn rapeseed harvest at that time. The project leaders expected that production would double in the coming years. However, even with a doubling of production, the plant would not be able to produce sufficient RME to meet the demand from a potential 5% RME blend (Ringström, 2005c). This showed that the problem of sufficient suitable land for the cultivation of rapeseed was still a barrier to expanding RME use.

With the expected increase in demand, Preem started to cooperate with the chemical company Perstorp AB in order to set up another RME plant to safeguard RME for a future 5% mix. In 2005, Preem and Perstorp announced the building of an RME factory in Stenungsund, where the Perstorp plant was located and existing infrastructure could be exploited. The expected date for starting production was late 2006 or early 2007. The initial capacity of the factory was expected to be 60 000 m^3 annually, but was expected to increase in pace with market demand (Perstorp, 2005). The capacity of the factory was 160 000 tonnes. Initially, the factory would import PVO from Germany and Denmark due to the limited rapeseed harvests in Sweden. However, the project leaders were open to Swedish feedstock if available. The interest of Perstorp in this project was to increase the share of products based on bio-based feedstock. Production at that time was based on fossil feedstock only. The RME production facility was a first step towards more sustainable production processes, in terms of meeting environmental demands and the increasing shortage of fossil fuels, at the company (Blomquist, 2006).

In August 2006, a 5% low blend of biodiesel in diesel was licensed by the government, which drastically increased the total use of biodiesel in the Swedish transport sector and is likely to explain the increase in the two following years (see Table 37) (Statens energimyndighet, 2011). The 5% mix was mainly RME, but fatty methyl esters based on for instance soy were included as well. This new mixture led to operating problems during low temperature in the winter of 2007. Consequently, during the winter period, the oil companies replaced the 5% blend with pure fossil diesel in the north of Sweden and a 2% RME blend in diesel in the south (Eriksson & Rehnlund, 2008). A potential explanation for the soy methyl ester mix was dependence on imports due to the limited rapeseed feedstock.

In parallel with the increase in demand for RME, the Karlshamn plant started production in May 2006 and Perstop in 2007 (Fock, 2007b). The lack of rapeseed production in Sweden meant that only half the feedstock used at the Karlshamn plant was Swedish, while Perstorp imported all its rapeseed oil from Germany and Denmark (Blomquist, 2006). However, due to higher rapeseed prices in the autumn of 2007, the Karlshamn factory halted production. Lantmännen had not secured their supply with price agreements. Other RME plants, however, like Perstorp managed to continue production because their supply of raw material was secured by long-term contracts (Fock, 2007b). The increase in RME prices is likely to be related to rising oil prices during this period. The production halt at Karlshamn continued into 2008 (Ecobränsle, 2009). However, production restarted, possibly due to the takeover of Ecobränsle in 2010 by the energy farming company Energigårdarna Eslöv (Ecobränsle, 2012).

At the end of the period, new means of producing biodiesel were emerging. Plans were made for a production plant for biodiesel from waste materials from the pulp industry, such as pine oil, palm fett acid, fett acid and methanol, in Piteå. Lars Stigsson, inventor and creator of the gasification company, Chemrec, managed the project. The production plant took the company name Sunpine AB. According to Stigsson, 'the production method means that we are not competing with the paper industry for forest resources. Instead we buy a waste product [from them]. Consequently, the representatives of the pulp industry are very interested. They see our business as a complement to their own' (Samuelsson, 2007b, translation by the author). In September 2007, four different consultative bodies, the Swedish EPA, Piteå municipality, the County Administrative Board and the Fishing Authority, were in favour of the project. The EPA, however, found it hard to judge the environmental effects and thus would only grant a test period of two years before a general approval was given (Samuelsson, 2007b). In 2008, the oil company Preem and the forest industries Södra and Sveaskog bought 60% of the shares of Sunpine AB. The rest of the shares were still owned by the entrepreneur and founder of the company, the engineer Lars Stigsson. The budget for the plant was SEK 250 million. In addition to investment, the different actors would contribute to the business. The forest industry Södra among others would deliver the feedstock, pine oil. The unrefined pine oil diesel would be shipped to Preem's refinery in Gothenburg for upgrading to biodiesel quality. The waste product, pine tar pitch, could be used for the production of high quality chemicals for the pharmaceutical and food industries. The construction of the plant was ongoing in 2008 and was expected to be ready for production in late 2009. The capacity of the plant was expected to be 100 000m^3 per year, equal to the fuel consumption of 100 000 vehicles driving approximately 10 000 km per year. Sunoil argued that they would be the first in the world to produce biodiesel from woody material on an industrial scale (Sunpine, 2008). Although somewhat delayed, the plant was built according to plan. Production of biodiesel began in April 2010. The goal remained to produce up to 100 000m^3 (Sunpine, 2010).

In addition to the use and production of low blend RME, attempts were made to introduce high biodiesel blends on the market in the late 2000s. One example was Statoil and Lantmännen, which in the autumn of 2006 launched their new diesel containing 15% RME and ethanol. Like earlier problems with low blend RME, this fuel mix did not fit the standard for Environmental Class 1 diesel. The resulting higher tax meant that the initiative was put on ice while Statoil and Lantmännen attempted to change the fuel's properties to conform with Environmental class 1 diesel standard. The aim was to introduce the fuel in the summer of 2007 (Samuelsson, 2007a), but media reports ceased which makes it likely that the initiative failed. The discontinuation of this initiative could relate to the failure of other projects by Lantmännen, such as the production halt at the Karlshamn RME plant.

Statoil was not alone, however, in attempting to launch higher blends of RME in diesel. At about the same time. OKQ/8 announced its plan to introduce an environmentally benign diesel with a 20 % mix of diesel from vegetable oils and animal fats. According to the environmental manager at OK/Q8, the aim was to increase the mix to 85% or sell a diesel fuel based on 100% biodiesel (Samuelsson, 2007a). The expectation at OK/Q8 was that the new diesel, called Diesel Eco 20, would reduce CO_2 emissions by 12% compared to conventional diesel. Although the fuel was a fit with Swedish environmental class 1 diesel standards, other problems emerged. The use of tropical palm oil as a main component of this diesel was seen as highly controversial. Weeks before the introduction of Eco 20 diesel, the WWF and Greenpeace were harshly criticizing the use of the palm oil (Ringström, 2007). Eventually, after widespread criticism in the media, the introduction of Diesel Eco20 was halted. OK/Q8 announced that Eco20 would not be introduced if Neste Oil could not provide 'less controversial fuels' (Samuelsson, 2007g).

Although OK/Q8 was the initial target for criticism, Greenpeace continued its criticism of other actors planning to use palm oil. The main target was a common project set up by the Swedish Post (Posten Logistik AB), Volvo Penta, Scania and the ferry company Waxholms Ångfartyg, which aimed to introduce a palm oil based fuel produced by Neste Oil to the cities Stockholm and Helsinki under the name NExBTL. It was hoped that the EU would support the project with the necessary finance, but after the criticism from Greenpeace the chances were very slim (Samuelsson, 2007f).

The use of RME and other biodiesels expanded throughout this period, particularly in the low blend niche. Both the general tax exemption and the legalization of higher biodiesel blends in 2006 created opportunities for niche expansion. Nonetheless, high rapeseed prices and problems with the use of tropical oils as feedstock hampered market expansion by higher blends and pure biodiesel, which is reflected in the slower expansion of biodiesel use after 2007 (see Table 37).

8.3.2. Biodiesel SNM analysis, 1997-2010

Biodiesel										
Year	**1997**	**1998**	**1999-2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
RME										
High blends/ pure	Various fleets									
High blend/ pure pumps					23	17	16	13	17	25
Low blend pumps	R2					R5 in all fossil diesel				
plants	Ecobränsle					Karlshamn				
								Perstorp		
Pine oil										
										Piteå

Table 39:Biodiesel development, 1997-2010

Network actors	Biofuel	Expectations	Key experiments	Learning	Socio-technical configurations
Farmers' organizations, a few fleet owners, oil distribution companies dominated the niche at the end of the period	focus on low blends	EU biofuel policy resulted in promise of low blend market. Promise of low blend RME as the most environmentally beneficial fuel was temporary widened to other biodiesels and from low blend to pure use. At the end of the period the focus returned to low blends alone.	Mainly low blend use, but experiments with higher blends met problems of legitimacy.	Technical and institutional lessons in this period helped to identify and standardize RME 5% blend as the most optimal use of biodiesel for emission reductions. Large increase in RME use after the general tax exemption indicates that financial means are crucial.	Low blend market niche with related infrastructure and standards. Limited high blend and pure use as well as an emerging pine oil diesel niche.

The farmers' organizations remained a central actor in this period. Initially, the farmers' organizations cooperated with the various other fleet owners and distribution companies, using higher RME blends as in the previous period. However, in the late 1990s and early 2000s the RME plant and various fleet activities were terminated, partly due to the ad hoc nature of the government and municipal support. With general government tax exemptions in 2004, low blend use expanded greatly, adding more fuel distribution companies and importers to the network, while higher blends and pure fuels became periphery activities. The fact that fuel distributors were regime actors is likely to have contributed to increased acceptance and expansion of the RME niche. Farmers' organizations had a less central role, but contributed to the low blend expansion through the start of new production facilities from 2006 onwards. Despite a failed attempt to expand high blend use in the second half of the 2000s, increasing network support for low blends indicates an increase in alignment of actor activities.

The promise of pure fuels articulated at the end of the previous period disappeared in the late 1990s. The niche expansion in this period was propelled by the expectation that RME in low blends would contribute the largest emissions reductions compared to other uses of RME. Particularly at the end of the period, these expectations were temporarily broadened to cover all types of biodiesels and the environmental benefits of higher blends and even pure fuels were recognized. These low blend and high blend expectations were facilitated by the EU Biofuel Directive, which stimulated government support from 2004. However, high blend expectations disappeared as a result of the *lesson* that increasing use of imported tropical biodiesels to support high blend expansion had negative environmental effects. Additional lessons were that the limited availability of cultivation acreage and feedstock prices set limits on the expansion of domestic RME production. Throughout this period, expectations related to low blend fuel remained high and were reinforced by positive lessons. One example was the identification and challenge to various institutional barriers that led to the standardization of RME 5% blend in diesel as the optimal use of biodiesel in conventional vehicles.

The tremendous increase in the RME use resulted in a low blend market niche and related institutionalization of low blend distribution by distribution companies based mainly on imported RME, but also included domestic RME production in the late 2000s. In addition, there was a small high blend and pure fuel niche with related distribution infrastructure as well as an emerging pine oil diesel niche based on waste oils from the paper and pulp industry. That the expansion took place after the general tax exemption indicates that financial support played a crucial role. However, as indicated by the failure of pure and high blend RME, such financial support needs to be coupled with strong niche internal processes to contribute to niche stabilization.

8.3.3. Biodiesel discourse development, 1980-2010

According to Sandén and Jonasson (2005), farmers were not only a large ethanol interest group, they were also the main supporters of biodiesel RME. As in the case of ethanol, the farmers' livelihood discourse and the increased power of the environmental discourse triggered the trials with rapeseed oil and RME in the 1980. This was also stated by the Swedish Oil Substitution Commission (1982:100), which indicated that the Swedish Oil-Seed Producers' Association was financing early trials in the 1980s with tractors (ibid). Hence, it is likely that an RME discourse existed in the farmer community in the 1980s.

However, the RME discourse had no chance of gaining ground due to competition with other biofuel options. Back in the mid-1980s, a commission investigating the potential for energy cropping to resolve the agricultural surplus problem argued that the cultivation of grain for ethanol production was more promising from an economic perspective than rapeseed cultivation for RME production (Motoralkoholkommittén, 1986a). SDAB also argued that RME was too expensive (SDAB, 1982: 97; Motoralkoholkommittén, 1986a: 88). It was the transesterification process, which transformed rapeseed oil to RME, which was said to make the fuel expensive. The use of unprocessed rapeseed oil was ruled out by the fact that it did not fit Swedish fuel standards. However, standards were considered less important in an emergency situation and thus rapeseed oil could be used as an emergency fuel. Nevertheless, according to SDAB, the need for large cultivation areas and competition with edible oils were additional arguments against the use of both fuel types (SDAB, 1982: 97; Motoralkoholkommittén, 1986a: 88).

Since bio oil and RME were not considered promising enough they did not gain any government funding in the 1980s. However, according to Carlsson and Nygren (1994), a tax regulation from 1961 on mineral oil for transportation implied that all fuel mixes with less than 70 percent by volume fossil oil were tax free. Hence, as outlined in the chapter on Swedish biofuel experiments, the majority of the experiments used a bio oil or RME blend of 33% in diesel to avoid tax. Carlsson and Nygren (1994) report an increased interest in RME use in the 1990s and an emerging idea that the 1961 tax regulation created 'unequal competition'. Consequently, the tax regulation was change in 1993. This meant that all transport fuels with more than 5% fossil oil were subject to tax, but all bio oil and RME use was exempted from energy tax (Carlsson & Nygren, 1994). In addition to the exemption from energy tax, RME like other biofuels was seen as CO_2 neutral and thus exempted from the CO_2 tax implemented in 1990 (Finansdepartementet, 1990).

As is outlined in the ethanol section, Swedish EU membership in 1995 meant that Sweden had to abandon this general tax exemption for temporary pilot project tax exemptions. Despite the temporary nature of the EU tax exemption system, the government argued that RME and ethanol should receive continuing tax exemptions according to previous national regulations (Persson & Åsbrink, 1997). Another shortfall caused by EU membership and related standardization was the withdrawal of Swedish financial support for rapeseed cultivation. This meant that farmers faced increased economic challenges to cultivate rapeseed (Sandén & Jonasson, 2005). Consequently, the local agricultural sector could not provide sufficiently cheap rapeseed for RME, which led to a rise in biodiesel imports after 1995 (Sandebring, 2004). Hence, Swedish EU membership in 1995 hampered attempts to introduce RME on to the policy agenda in the mid-1990s.

However, the discourse started to gain some ground in the second half of the 1990s. This was a result of the increased embedding of the RME discourse in the growing environmental discourse, which was reflected in two commissioned reports, by the Alternative Fuel Commission (Alternativbränsleutredningen, 1996) and the Communications Committee

(Kommunikationskommittén, 1997). Both commissions advised the government to give a general energy and CO_2 tax exemptions to all biofuels, thus also RME. In addition, the Alternative Fuel Commission (Alternativbränsleutredningen, 1996) added the need to implement low blends of not only ethanol in gasoline but also RME in diesel to reduce CO_2 emissions (ibid.). As a result of the conclusions of the two reports, the government promised to grant general tax exemptions to all biofuels, including RME. This was mentioned in three government bills: the Budget Bill (Persson & Åsbrink, 1997), the Environment Bill (Peterson & Lindh, 1998) and the Transport Policy Bill (Persson & Uusman, 1998), all agreed by parliament.

However, the two reports were not totally positive about RME. They argued for additional scientific research and debate. In 1994, scientists had noted increased NO_x emissions from the use of RME in diesel engines (Egebäck & Westerholm, 1997). According to Egebäck and Westerholm (1997), these NO_x emissions could be reduced by adjustments to the engine technology. Both the Swedish Environmental Protection Agency (EPA) and parts of the transport industry recognized this problem (Miljörapporten, 1997a). As a short-term solution, the Swedish EPA, Egebäck and Westerholm and the Alternative Fuel Commission recommended the use of RME in low blends, which was considered to deliver much better environmental benefits (Miljörapporten, 1997a; Alternativbränsleutredningen, 1996). Similar arguments were used by oil distribution companies, which shifted the focus from pure fuel to low blends, particularly 2% RME, in field experiments in the late 1990s (Miljörapporten, 1997b; Miljörapporten, 1998d).

Nonetheless, the criticism did not end there. The Energy authorities argued that RME cultivation resulted in the release of Nitrous oxide (N_2O), which is a prominent greenhouse gas. Moreover, the Energy Authority repeated a variant of the limited feedstock argument used in the 1980s by arguing that RME could never be more than a niche fuel since rapeseed production was limited by the availability of suitable cultivation areas, which had to be shared with the necessary area for food oil production. The main stakeholders defending RME were the farmers' organizations. They objected to the findings on the release of N_2O and argued that RME use reduced local emissions and was 'a technically very good substitute for diesel'. Like the recommendations by the EPA and the scientific advisers, farmers' organizations promoted low blends. Alongside attempts to embed the RME discourse in the dominant environmental discourse, the agricultural coalition presented socio-economic arguments for RME, such as the increase in regional employment, in order to link up with the growing regional development discourse (Kommunikationskommittén, 1997: appendix). Despite the defence of the RME option, the number of negative reports on RME increased, which resulted in the withdrawal of plans for large scale RME introduction by the oil distribution company Preem among others (Miljörapporten, 1997a). This indicates a continuing problem for the RME discourse with gaining ground (Miljörapporten, 1998d).

However, lobbying activities and political statements breathed new life into the RME discourse. Parliamentarians from the Christian Democrats and the Left Party urged the government to support RME. The arguments for supporting RME were mainly CO_2 reduction, but also to reduce dependence on oil and stimulate employment in the countryside (Persson, 1997; Gylling, 1998). Hence, it may be concluded that arguments attempting to make stronger links with the environmental discourse played a central role, while support from the oil substitution and regional development discourses was also mobilized by the RME lobby. In addition, government statements in the 1998 Environment Bill and the Transport Policy Bill helped to increase the stability of the RME discourse. These bills argued for an exemption from tax for all biofuels, and that the use of a higher RME blend, of 5% as used in the rest of Europe, was likely to have a positive effect on the environment. As a result, RME importers and producers drew up new plans and activities in line with the low blend promise while applying for tax exemptions (Miljörapporten, 1999a). This is likely to have increased the legitimacy of the RME discourse. Moreover, the reference to EU standards to gain acceptance for the 5% RME blend indicates that EU legislation was not only a barrier but also created an opportunity for Swedish RME expansion.

Nevertheless, as is outlined in the ethanol section, the message of the Ministry of Finance in 1999 was that it would not grant any new biofuel tax exemptions. Only one ethanol project was granted funds. To explain this decision, the Ministry of Finance referred to the many negative publications on RME, arguing that funds should not be wasted on biofuels activities that had uncertain environmental benefits (Miljörapporten, 1999b; Miljörapporten, 1999d). Once the government decided not to give the promised tax exemption, the companies producing RME expressed uncertainty about the future of the fuel and distrust of politicians. According to Kjell Lindqist at AgroOil: 'The risk is great that there will be a halt in the development of biofuel. The 'no' shows that it isn't possible to trust political decisions' (Miljörapporten, 1999a, translation by the author).

The negative publicity about RME meant problems with gaining continued support from not only the government, but also local authorities. After the debate about RME emissions in the late 1990s, RME vehicles, which were initially supported by the cities of Stockholm, Göteborg and Malmö, were withdrawn from 'environmental car' support programmes (Sandén & Jonasson, 2005). In Gothenburg, this meant that the city excluded vehicles driving on pure RME from the environmental vehicle definition in 2001, which prevented them from enjoying free parking and other local benefits from 2003 onwards (Samuelsson, 2004g). The withdrawal of support at both the national and the local levels indicates a weakening of the RME discourse.

Nonetheless, lobbying for RME continued. The RME coalition was aided by collaboration with the ethanol coalition and the formulation of a broader biofuel discourse. As is described in the ethanol section, this biofuel discourse saw the implementation of conventional biofuels as a necessary bridge to further, more advanced and environmentally friendly fuel alternatives. The ethanol section also describes farmer-led RME production companies and conventional oil companies with an interest in RME distribution as the main RME coalition actors lobbying for tax exemptions (Miljörapporten, 2000b).

Eventually, the Ministry of Finance made some concessions. It was decided to grant ongoing RME projects a tax exemption for 2002 in order to prevent a steep increase in price. Ethanol, however, did not gain a tax exemption. The reason for supporting RME only was that, unlike ethanol, it had not had much previous government support and thereby had more potential to live up to its promises (Miljörapporten, 2001a). As is reported in the ethanol section, the decision to implement the EU Biofuel directive increased the legitimacy of the first-generation biofuel discourse. Both ethanol and RME gained temporary tax exemptions in 2003, which was followed by a long term biofuel tax exemption from 2004 to 2008.

As a result of the new law, there was a particularly large interest from fuel distributors in introducing low blend RME in diesel. This was probably due to the fact that the new tax exemption law (see Persson & Ringholm, 2003) allowed anyone to apply for an exemption. Nevertheless, the fuel distribution companies that started to mix 2% RME in their diesel were faced with a problem. Paradoxically, the permitted 2% mix in environmental class 1 diesel degraded the fuel to a lower, less environmentally friendly class. This meant that fuel distribution companies had to pay higher taxes for the RME mixed diesel or risk being fined if the correct taxes were not paid. As a result, an RME coalition of farmers' organizations sent a complaint to the Ministry of Environment together with SPI and Bilsweden, requesting the government to adjust the Environmental Class 1 Diesel standard to include not only a 2%, but also a 5% RME blend and avoid this becoming mixed up with Environmental Class 2 Diesel and thus higher taxes (Samuelsson, 2004d). In addition to the lobby, the need to introduce low blend RME in diesel was supported by the Commission for the Investigation of Renewable Transport Fuels (Sandebring, 2004).[90]

RME was not part of the debate around the obligatory introduction of alternative fuel pumps at filling stations, commonly called the 'pump law', since pure RME was considered not to contribute sufficiently to emission reduction compared to other alternatives such as ethanol. At first sight, the exclusion of RME due to its poor environmental qualities seems a negative development, but it profited the RME discourse. The large resistance to the pump law promoting pure biofuel distribution meant that increased support and lobbying was directed to the use of low blends of biofuel in diesel or gasoline. According to Ringström (2005b), this meant that many oil companies that were negative about the pump law joined the lobby to increase low blend RME to 5%. Due to additional political pressure by the many oil companies, the Swedish Road Authority (Vägverket) developed a legislative proposal for a 5% blend of RME in diesel, which was to be classified under the Environmental Class 1 diesel label (Ringström, 2005b). As a result, the RME discourse was strengthened and new production sites were planned (Ringström, 2005c). The main argument used by the farmer driven RME coalition in order to increase the RME blend in diesel was the reduction of CO_2 and thus prevention of climate change. The second argument related to socio-economic developments and thus the regional development discourse and the livelihoods of farmers (Svensk raps, 2006; LRF, 2007). Eventually, in 2006, a 5% blend in diesel was agreed by parliament and the plans for large-scale RME plants could proceed (LRF, 2007). In addition, the government prolonged the tax exemption for all biofuels to 2013 (Jonsson, 2007).

The progress of the RME discourse was particularly remarkable, given the fact that there was a scientific discourse repeating the criticisms raised in the late 1990s (Jonsson, 2007). Moreover, as is outlined in the ethanol section, there was a lobby against conventional biofuels with an interest in furthering second-generation synthetic gas based fuel development. This lobby argued that conventional biofuels were expensive, did not have environmental benefits and did not contribute to technology development and thus did not pose any bridge to future alternative fuels (Hådell, 2001). Like ethanol, RME became an object of criticism by the increasingly international anti-biofuel discourse, which in addition to the negative environmental effects of conventional biofuels referred to competition with foods and degrading biodiversity, to mention just a few problems.

In the wake of the growing stability of the RME discourse, the discourse was widened to a general biodiesel discourse. The broader discourse was a result of the changing tax exemption rules in 2004, which allowed anyone to import biofuels from abroad. Hence, the use of domestic and imported RME was replaced by the possibility of using a variety of plant oils, which increasingly challenged the previous criticism of biodiesel as only a niche fuel. In addition to the low fuel mixes used, certain actors tried to implement new diesel fuels with high mixes of biodiesel, arguing that larger CO_2 reductions could be achieved. OK/Q8 was targeted for particularly severe criticism since its vegetable oil used came from Malaysian palm oil. According to WWF, Greenpeace and the Swedish Society for Nature Conservation (SSNC), palm oil cultivation in Malaysia destroys great areas of rainforest, and thus reduces biodiversity and increases CO_2 production (Ringström, 2007; Samuelsson, 2007c). At a later stage, more tropical biodiesel users were targeted for critique (Samuelsson, 2007f). As is described in the section 8.3.1 on Swedish biofuel experiments, many of the biodiesel projects were halted as a result of the growing anti-biofuel discourse. In fact, the negative effect of the

[90] The name of the commission in Swedish: Utredningen för förnybara fordonsbränslen.

anti biofuel discourse on biodiesel development in general is likely to be higher than on ethanol, due to the relatively greater popularity of ethanol compared to the biodiesel discourse in Sweden.

8.3.4. Biodiesel discourse analysis, 1980-2010

Policy	Level	Year	Type	Size SEK	Explanation
Fuel tax	Government	1961-1993	Regulation	?	The 1961 mineral oil tax law implied that fuels with more than 30% bio oil or RME were exempt from tax.
Pure vegetable oil	Industry	1980-1984	Field trial	?	Agricultural vehicle trial run by agrarian association.
R33	Industry	1981-1984	Field trial	?	Tractor trial run by Institute for Agricultural Machinery
RME	Industry	1990-	Field trial	?	Farmers carry out small scale trials with high and low blends
CO_2 tax	Government	1990-	Regulation	?	CO_2 tax on fossil fuels. All biofuels exempted.
Energy tax	Government	1993-1994	Regulation	?	A general tax exemption for bio oil/RME introduced.
EU tax exemptions	EU, government	1995-1997	regulation	?	As a result of EU membership, all biofuels granted temporary tax exemptions.
	EU, government	1997-2001	regulation	?	No new tax exemptions granted for RME
	EU, government	2002-	regulation	?	2002-2003 tax exemptions increasingly granted. General tax exemptions from 2004.
RME production	government	1993-1998	Production	?	1993-1994 Svenskt Ecobränsle produces RME, 1995-1998 first plant is running.
Pure RME distribution and use	Industry, municipalities	1996-1997	Field trial	?	Fleet trials in Stockholm by municipalities, taxi companies, delivery firms. Distribution by Statoil and later also OK.
RME standard	Government	1996-	regulation	?	1996: Swedish RME standard, superseded by EU standard in 2003.
R2 low blend	Industry	1990s-2005	Field trial	?	Successive increases in use of 2% RME in diesel.
Clean vehicles	Municipalities	1998-2000	support	?	Clean vehicle projects in Stockholm, Gothenburg and Malmö support pure RME, but cease around 2000.
R5 low blend	Industry	2006-		?	Government allows 5% RME in diesel. Oil distribution companies successively mix ever more RME in their diesel.
RME production	Industry	2006-	Market creation	?	Karlshamn plant runs 2006-2007. Perstorp plant starts in 2007 and is still active.

Table 40: RME-related policy development, 1960-2010

Biofuel	Discourse	Mobilization/ impact of wider discourses, events and policies.	Discourse coalition	Target audience	Key activities, strategies	Resulting space/ policy creation or disruption
RME use mainly low blend, late 2000s other biodiesels and higher blends	RME contributes to oil substitution (particularly good diesel substitute), local emission reduction and the economy of farmers. Mainly promotion of low blends, but temporal promotion of exotic biodiesels and higher blends in late 2000s.	Embedding in farmer livelihood /regional development discourse, environmental discourse	Farmer organizations led discourse, with temporal support fuel distributors and general biofuel discourse.	Government, wider public for legitimacy.	Lobby activities hardly visible, only in selected reports and policy debates	Limited tax exemptions prior to 2003, temporal incentives for pure RME on a local level. Post 2004, increased tax exemptions support of low blend RME and standardization of a 5% blend with support from wider biofuel discourse.

Like many other biofuel discourses in the 1980s, RME was seen as a means to substitute for oil, reduce local emissions and aid the economy of farmers. Unlike ethanol, RME was said to be a 'technically very good substitute for diesel' since it did not require any diesel engine modifications. Despite this, it was in the mid-1990s, when the discourse first changed to emphasize low blend RME as particularly suitable for global CO_2 emission reduction and regional economic development, that the discourse gained ground. At the end of the 2000s, the discourse widened to include other biodiesels as well as the use of higher blends.

Initial discourse development was facilitated by embedding in the farmers' livelihood discourse, which later became a regional development discourse. Embedding in the environmental and biofuel discourses was facilitated by increased concern for CO_2 reductions and preparations for and the publication of the EU Biofuel Directive. However, the embedding in the environmental discourse was not as straightforward or successful as in the case of ethanol and biogas, due to recurrent criticism of the environmental qualities of RME.

Farmers' organizations led the RME coalition. Temporary lobbying was also carried out by fuel distributors and other actors, as part of the wider biofuel discourse coalition. RME lobbying activities were hardly visible, except in some political debates and reports. The lobby tried to gain support from the government and acceptance from the wider public. The lack of committed coalition actors and visible lobbying activities explains part of the weak discourse development. Additional factors hampering discourse development were competing biofuel discourses claiming that RME was only a 'niche fuel' due to its limited cultivation acreage, as well as the argument by synfuel and the anti-biofuel lobby that biodiesel had only limited or no environmental benefits.

The limited RME discourse development explains part of the limited financial incentives given to RME in comparison to other biofuels prior to 2003. At the local level, support measures for pure RME were time-limited, while other pure biofuels gained continuous support. Post-2004, support for low blend RME increased along with general tax exemptions, the standardization of a 5% blend and limited protection for pure RME by means of the biofuel pump law. The anti-biofuel discourse prevented attempts to widen the discourse with exotic biodiesels and higher blends in the late 2000s. The acceptance of low blends alone shows the limited institutionalization of biodiesel compared to other biofuels.

8.4. THE RETURN OF SYNTHETIC BIOFUELS (SYNFUELS), 1997-2010

This section describes the return of synthetic gas fuels (synfuels) in the late 1990s to 2010, having been dormant since the cessation of methanol experiments in the 1980s. First, I present the developments of the methanol, DME and FT diesel niches followed by an SNM analysis. Second, I describe the political processes leading up to synfuel policy followed by a discourse analysis.

8.4.1. Synfuel niche development, 1997-2010

Synthetic gas (syngas) liquefaction technology had been dormant in the last period, but it experienced a revival in this period. The old methanol promise returned together with new synthetic fuel alternatives, such as Dimethyl Ether (DME) and Fischer-Tropsch (FT).

Methanol

Methanol lost popularity in the late 1980s but the biomass gasification technology part of the methanol production chain was kept alive by the ambition to produce more efficient energy and heat from biomass (Sandén & Jonasson, 2005). According to Sandén and Jonasson (2005), many of the researchers working on methanol had focused on bottlenecks in the gasification process and kept their activities going at research institutes focused on gasification research or at the consultant company Ecotraffic, some of them founded. Ecotraffic specialized in the field of energy and the environment.

Ecotraffic's interest in methanol as an alternative fuel led to a failed attempt to set up a methanol production plant in the early 1990s (Carlsson & Molin, 1991). However, by the late 1990s vehicle producers were paying renewed attention to methanol due to its potential to act as a feedstock for fuel cell vehicles. However, the promise was weak since the technology was immature and seen as a long term option only (Ahlvik & Brandberg, 2002). Ecotraffic and a few other methanol proponents were still interested in developing the technology due to the higher efficiency of methanol compared to ethanol. Methanol was also expected to use a greater variety of feedstock, which required less cultivation acreage and resulted in lower production costs. A combined production of methanol for heat and energy was argued to be most cost-efficient since the output of products could be adjusted to the season (Miljörapporten, 1998a; Miljörapporten, 1998c; Samuelsson, 2004f). This is very much in line with the plans for the Nynäshamn gasification and methanol project in the 1980s, which were never realized.

In 2002 Ecotraffic made a new attempt to set up methanol production in collaboration with Gothenburg City. The renewed interest in methanol was motivated by the announcement of the upcoming EU Biofuel Directive, setting biofuel implementation targets for 2005 and 2010. Ecotraffic carried out an assessment of methanol as a vehicle fuel. The conclusion was that methanol had great benefits compared to gasoline with regard to health and environmental impact. The only negative point was the immediate toxicity of methanol, which was somewhat worse than that of gasoline. At that time there were very few vehicles able to run on methanol in Sweden – only the first-generation FFVs made by Ford Taurus vehicles that were imported in the 1990s to run on ethanol. Another, preferable way to introduce methanol was as a low blend in gasoline. The current fuel standards set the methanol blend to a maximum of 3%. A future possibility was to use M85 and/or M100 in fleets (Ahlvik, 2002). However, no additional information appeared after the publication of this assessment report and there was no action related to methanol taken on by Gothenburg City. Hence, it is likely that the project was not considered feasible.

In parallel with the developments by Ecotraffic, the gasification technology company Chemrec had an interest in methanol. Chemrec had been working with black liquor gasification since 1985. The idea of processing black liquor to methanol and/or Dimethyl Ether (DME) via gasification emerged in 2000 (Modig, 2005; Fallde et al., 2007). Chemrec considered the DME process more interesting than methanol, and more on the Chemrec process is outlined in the DME section below.

Dimethyl Ether

New transport fuels emerged based on the syngas route. In the mid-1990s, the promise of bio-based DME as an alternative transport fuel reached Sweden from Denmark, where Haldor-Topsoe rediscovered the fuel quality of DME (Sandén & Jonasson, 2005). This inspired several actors to start investigating DME as a fuel option, most notably Växjö municipality, Volvo and Chemrec.

The interest of Växjö in DME was triggered by a policy goal set out the municipality in 1996 to become free of fossil fuels. The decision was partly based on growing concerns about climate change as well as the great success with which the municipally owned energy company Växjö Energi had reduced fossil fuel use by using biomass in the production of heat and energy (Sandén & Jonasson, 2005; Fallde et al., 2007). However, the transport sector had not yet been properly tackled. Due to the promise around DME, Växjö municipality managed to gain funds from the Biofuel Programme managed by KFB. These funds were used to examine the potential for producing DME from wood for use in the south of Sweden. The project was assigned to the contract researcher Atrax Energi. The results were presented in mid-1997 and included a rough timetable for market creation as a short-term goal, and the set up of a production facility for DME in connection with the facilities of Växjö Energi and large scale use as a long-term goal. The results were positive enough for Växjö municipality to start a DME project. Växjö Energi contributed to the financing of Swedish participation in the IEA Advanced Motor Fuels (IEA-AMF) group. Volvo also became a member of the working group after defining DME as the main alternative fuel for heavy vehicles in the future (Fallde et al., 2007).

Volvo had developed a genuine interest in DME fuel due to its particularly high performance and low emissions. DME has a higher cetane number than diesel, meaning that DME has a short ignition time and cleaner combustion. Eventually, after years of engine research, a DME truck was developed in 2004 and tests with DME started in Växjö in 2005 (Sandén & Jonasson, 2005; Månsson, 1998).

In Växjö, the municipality was not the only force behind DME production, a broader interest in bioenergy and novel technology at the local level contributed to the development. One example was the promotion of bio energy technologies by the higher education institute in Växjö, later known as the University of Växjö. Another example was the creation of a cooperation of local bio energy businesses, called Bioenergigruppen AB, to promote bio energy and contribute to research. The most crucial component for DME development was the availability of a nearby gasification pilot plant, Biomass Integrated Gasification Combined Cycle (BIGCC), in the neighbouring town of Värnamo run by the energy company Sydkraft. The gasification plant started running in 1996 as a result of R&D funds for a gasification project that Sydkraft started in 1990 (Fallde et al., 2007). According to Fallde et al. (2007), it was the first plant in the world to manage to use the combined cycle technology to produce electricity and heat successfully. The results of the tests run at the plant from 1996-1999 showed a well functioning technology, which could handle a great variety of biomass. While the project was expected to become competitive in the future, electricity prices were currently very low which hampered continued experimentation at the plant. Since the

Värnamo plant was not far from Växjö and the plant had no future use, Växjö municipality saw an opportunity to modify the plant to a DME pilot and in this way fast forward the original plans for constructing and producing DME. An evaluation showed that it was possible to modify the plant to produce syngas, which could later be used for DME production in a separate DME synthesis installation. The Swedish Energy Agency was positive about the idea that the pilot plant could continue to be useful. As a result, Växjö sought European partners for the DME project. However, Växjö failed due to the limited interest in this technology internationally, but gained Volvo as a partner and could also profit from Volvo's DME truck project (Fallde et al., 2007).

Together with Volvo, more detailed feasibility studies were carried out. Moreover, under the name the 'Bio-DME Project', new attempts were made, starting in 2001, to raise funding in collaboration with the Swedish Energy Authority. Their initial failure to gain funds from the EU did not stop them and new applications to construct a suitable gasification process were submitted the following year. The University of Växjö was the lead applicant since the university was seen as having a greater chance of gaining funds compared to Volvo and Växjö municipality. While searching for funds, the municipal energy companies Växjö Energi AB and Värnamo Energi AB set up the company Växjö Värnamo Biomass Gasification Centre (VVBGC). In 2004, VVBGC took over the Värnamo plant from Sydkraft. The goal was to build a European research centre for development and demonstration of biomass gasification. In parallel with the takeover of the plant, the EU's sixth Framework Programme, the Swedish Energy Authority and a series of other parties were granted funding for the Clean Hydrogen-Rich Synthetic Gas (CHRISGAS) project (Fallde et al., 2007). The five-year project started in September 2004. Its goal was to set up a large scale plant demonstration of the production of hydrogen-rich synthetic gas that could be a resource for biofuel production. Hence, the biofuel production step was not part of the project, but the expectation was that the plant could be connected with a biofuel processing installation at a later stage. However, at a late stage financial problems emerged. The costs of the project were estimated at SEK 400 million and financers for the last SEK 68 million could not be found. What made this particularly difficult for the project was that the Swedish Energy Agency had set a condition that all the investment must be in place before it released its promised funding of SEK 182 million. The reason for this condition was that it wanted the commitment of industrial partners, which it saw as the only way to get a project commercialized in the future. Consequently, realization of the demonstration gasifier needed to produce bio-synthesis gas was stalled in December 2007. While limited research activities were continued based on previous grants gained, efforts to resolve the financial deadlock were still ongoing in late 2008. The Swedish Energy Agency released a grant of SEK 0.4 million to enable CCBGC to continue its efforts to find private investment (Bengtsson, 2008). Continued efforts were made to attract investors, but also failed. One of the reasons for this failure, according to the VVBGC, was the economic crisis of recent years which has made industry more cautious about long-term investments (VVBGC, 2011).

Unlike the Växjö case, the choice of DME as end product was less clear when Chemrec and partners developed a pilot gasification installation in Piteå. The initial aim was to better deal with a waste product from the pulp and paper industries, black liquor, made up of chemicals and organic residues. To recycle the chemicals and increase the energy efficiency of the pulp process, normal practice over the past 70 years was to burn the black liquor. However, this process had many problems, which led to experimentation with alternative processes such as gasification in the mid-1980s. The gasification process was managed by Chemrec AB in 1989. After experimental pilots, Chemrec settled for pressurized gasification with oxygen blown technology. In collaboration with the forestry company, AssiDomän, a full scale gasification plant was set up in Piteå. The investment was approximately SEK 240 million, of which the government body FABEL[91] contributed half. Research on the gasification process was carried out in collaboration with Umeå University and the energy technical centre (Energitekniskt Centrum, ETC) in Piteå, which was a cooperation between the Piteå municipality and the higher technical institute in Luleå, now known as Luleå University. Additional R&D programmes contributed funding to the gasification process. Among them was the Black Liquor Gasification (BLG) programme – started in 2001 by the ETC and Chemrec in order to tackle the process bottlenecks – financed by the Swedish Energy Authority and project partners (Fallde et al., 2007).

Until the turn of the century, the focus of the gasification process was the production of renewable electricity in order to make the pulp plants more energy efficient. In 2001, however, Chemrec became increasingly intrigued by other uses for the syngas produced by the gasification process. In particular, the production of vehicle fuels like methanol and/or DME became of interest. One of the reasons behind the interest in transport fuels was the suitability of Chemrec technology for fuel production since the fuel synthesis, like the oxygen blown gasification process, needed high pressure and a high heat content. The fit between the two technologies made the process relatively simple, energy efficient and cheap (Fallde et al., 2007).

Chemrec joined the EU RENEW project with the ambition to explore the potential to produce vehicle fuels. The RENEW project started in 2004 and was led by Volkswagen. The project involved various biomass to liquid (BTL) actor groups from all over Europe, such as Fischer Tropsch specialist CHOREN in Germany and ethanol specialist Abengoa in Spain, and related actor networks. Institutes and actors from nine countries participated. All the fuel routes investigated were based on biomass gasification. The main objective was to investigate the potential of various BTL routes for vehicle fuel production (Chemrec, 2008). The participants in the RENEW group from Sweden were Chemrec, the pulp and paper industry Södra Cell, Volvo, the pulp and paper research institute STFI and Ecotraffic. Part of the EU project was the development and experimentation with a small (350 tonne) pilot plant for the production of DME and methanol from black liquor. The plant was designed to be flexible. It could produce anything from 80% methanol and 20 % DME to 100% DME. However, the focus was on the production of DME for heavy vehicles. The potential production of methanol was seen as suitable for upgrading pure plant oil to biodiesel or for blending in gasoline together with ethanol. This was allowed under the current gasoline specification (Lindblom & Landälv, 2007). In the final report of the RENEW project, it was concluded that the Chemrec process for renewable fuels was the most energy- and cost efficient process and had a CO_2 emissions reduction of more than 95%. The cost estimated was at €0.5/litre diesel equivalent, and the efficiency 69%. The technology was also considered sufficiently mature for up-scaling. Hence, together with the Choren FT-diesel process, Chemrec's DME/methanol process was recommended for demonstration at an industrial scale (Chemrec, 2008).

In addition to the collaboration with various EU partners, the research network was broadened at the national level. The BLG programme, which financed part of the development of the plant in Piteå post-2004 and set up-scaling as its goal post-2007, is likely to have contributed to the expansion of this network. The programme partners were no longer just ETC and Chemrec. Research was also carried out by Luleå Technical University, Umeå

91 FABEL was a government body that gave support to technologies for energy production based on biomass and was created as a result of the three party agreement in 1991 in which bio-based energy was put forward as a alternative to enable nuclear energy phase out (Fallde et al., 2007).

University, Chalmers Technical University, the STFI and the research institute Swedish Corrosion Institute (Korrosionsinstitutet). Financing was received from the Energy Agency, the foundation for strategic environmental research, Mistra, the County Administrative Board of Norrbotten, the forest owners' association, Sveaskog, SCA and Södra, the government energy company Vattenfall, the packaging company Smurfit Kappa and Chemrec (Fallde et al., 2007).

The expectations for DME technology had been high since 2006, when Chemrec made clear that the gasification process could be ready for commercialization in 2010. The plan was to build several demonstration plants in Sweden that were 15-20 times bigger than the pilot in Piteå. The network hoped to demonstrate the maturity and availability of the technology and stimulate further market expansion (Fallde et al., 2007). Additional support for the technology development process was provided by Volvo. The company had made great progress in the development of DME engines for their heavy vehicles. Volvo also invested in Chemrec to show its commitment to the fuel process. In 2007, it became clear that Chemrec together with Volvo and Dupont were interested in building a demonstration plant for DME production. They put in an application for funds to the EU Seventh Framework Programme (FP7) (Fallde et al., 2007). Financial support was granted under FP7 together with additional funds from the Swedish Energy Agency in September 2009. The demonstration plant in Piteå was announced as the world's first bio DME plant. The building of the plant is part of the project BioDME in which Chemrec, Haldor Topsøe, Volvo, Preem, Total, Delphi and ETC are involved. Volvo is the project leader. The estimated cost of the plant is around SEK 150 million (€ 14 million). Every project partner has a different task to contribute to the commercialization of DME. While Chemrec provides the gasification process, Preem will construct four DME filling stations and Volvo will construct 14 DME trucks. A follow-up project as part of the demonstration plant plans is the construction of an industrial-scale plant with the capacity to fuel half of all freight road transport with DME. In addition, global expansion plans were made. According to Chemrec, an annual production of over 30 million m^3 of diesel equivalent is possible based on the available international black liquor feedstock (Chemrec, 2009). After some years of delay, the demonstration plant in Piteå was up and running in 2012. The DME produced is said to be highly fuel efficient and extremely clean with a potential CO_2 reduction of 95% compared to conventional diesel. In April 2012, Preem had set up four filling stations in four cities in Sweden, which in turn fuelled 10 Volvo DME trucks (Chemrec, 2012).

Fischer-Tropsch

Alongside other fuels developed by means of gasification technology, Fischer-Tropsch emerged as an option in this period. The process was developed to transform coal to diesel fuel in Germany in the 1920s and is currently exploited by large oil companies such as Shell and Sasoil using coal or natural gas as feedstock. The end product was a diesel that could be used in normal diesel vehicles without engine adaptation. More recently, the development of Fischer-Tropsch diesel from biomass gained in interest (Wikipedia, 2011). While the ambition of various Swedish entrepreneurs has been to produce FT-diesel from biomass, FT practice was until 2009 based only on natural gas.

The R&D company Oroboros AB in Gothenburg was one of the first to introduce FT-diesel to Sweden. Oroboros applied a type of Fischer-Tropsch synthesis to natural gas and patented this as Ecopar diesel. The company started in 1998 in environmental consulting and research (Ecopar, 2008). In the autumn of 1999 trials with the fuel were carried out in a one cylinder truck engine at Chalmers University of Technology. The conclusion of these trials was that there were no technical problems connected to the use of Ecopar fuel in conventional diesel engines. Moreover, the emissions were lower with Ecopar compared to tests with the cleanest fossil diesel, Swedish environmental class one diesel. As a result, the FT-fuel was considered very promising and Oroboros set-up a technical specification for the production of the fuel (Aldén, Eklund, & Larsson, 2002). Despite plans for an early introduction (Wikipedia, 2008), the fuel was not presented officially by Oroboros before January 2001 (Aldén et al., 2002).

The next step was to test the fuel in a field trial. With financial support from the county of Västernorrland, the first Swedish field experiment with natural gas based FT-diesel was initiated under the project name 'Bränsletest på Holms lantbruk', literally translated: Fuel Test at Holm's Farm (Aldén et al., 2002). According to the website of the company FramTidsbränslen, this trial was the first trial using synthetic diesel in the whole of Europe since the Second World War (Framtidsbränslen, 2008). This however might be open to debate, given the activities of Shell and Sasoil mentioned above. The aim of the trial was to evaluate the process route gas to liquid (GTL) as fuel for diesel vehicles without any modification of the engine. The farm Holms Lantbruk AB was the owner of the project while Bengt Aldén of the consultant company Energocon[92] was the project manager. Oroboros AB provided the fuel and a variety of companies with vehicles in the county of Västernorrland participated in the trial. The vehicles provided were: two tractors and one loader by Holms Lantbruk AB, one car by Energocon, another by the taxi company Sollefteå Taxi AB, one truck by the brewer Zeunerts AB, and one bus from Werner Westins Buss AB. The trial with six vehicles and one loader started in October 2000. For comparative reasons, the vehicles ran for the first two months on Swedish class 1 diesel. Driving journals were kept to note any particular changes in fuel consumption, drivability, smoke and smell. From January to November 2001 the vehicles switched to Ecopar. Five rental cars from the rental car company Sahléns Bil AB were added to the trial. To facilitate the distribution of fuel, the first FT-diesel filling station was set up in Sollefteå, where the majority of the vehicles were running. Eventually, in the last weeks of 2001, the vehicles were tested with diesel once again. The goals set out for the programme were reached. There were no problems running conventional diesel vehicles on FT-diesel. The problems that occurred were related to mechanical problems, and thus not the fuel. The drivers of the vehicles saw only benefits when using FT-diesel instead of conventional diesel, such as less smoke and bad smells. In addition, two independent emissions tests indicated generally lower emissions for FT-diesel compared to diesel (Aldén et al., 2002).[93]

After the initial trial, FT-diesel was introduced on the Swedish market in 2002 (Aldén et al., 2002). Oroboros AB started selling the fuel mix Ecopar and announced that it would deliver the bio-based FT fuel under the name Biopar once sufficiently mature (Ecopar, 2008). The commercialization of the fuel made additional trials in fleets possible. One of the first to use Ecopar was Sveaskog, which had 30 of its forest machines running on Ecopar. Due to positive experiences with the work environment for the employees in particular, Sveaskog wanted make the change to Ecopar fuel permanent. The implementation by the government of an increased environmental tax on Ecopar, however, led Sveaskog to reverse its ambitions due to high costs. Additional trials were carried out by various companies, such as Kynningsrud Kran AB, and with municipalities such as Mariestad, which led to increased substitution in

---

92 Bengt Aldén was also the writer of the report and later the president of FramTidsbränslen, which led the further implementation of FT-diesel in the BioFuel Region.

93 The test showed a decline in particle matter and HC when using FT diesel instead of environmental class 1 diesel. The measurements of NO_x emissions were more ambiguous, showing reductions in the first test but an equal amount of emissions in the second test. The emissions of carbon monoxide were higher with FT-diesel compared to conventional diesel. Finally, for non-regulated emissions such as aldehydes and mutagens like PAH (Polycyclic aromatic hydrocarbons), lower emissions were noted with FT diesel use (Aldén et al., 2002).

diesel fleets by Ecopar (Tandberg, 2005). The emissions results in 2008 were more positive than those first carried out by Oroboros in 2001. According to the Ecopar homepage (Ecopar, 2008), use of the fuel reduced over 90% of the carcinogenic emissions and up to 50% of nitrogen oxide emissions compared to conventional diesel. Eventually, in 2006, Oroboros AB changed its name to EcoPar (Ecopar, 2008), probably to be able to market the product better.

The success of this initial trial with FT-diesel in Västernorrland generated an additional FT company in 2002 - Framtidsbränslen (Future Fuels). The aim was to promote the development and use of biobased FT-diesel. Like Oroboros, this was done by introducing and facilitating the use of fossil based FT-diesel, distributed by the company. Framtidsbränslen did not produce its own fuel from natural gas, but imported it and created its own fuel mix, Paradiesel. Since the start of the company, efforts were made to set up an international network in order to better keep up with developments in the field of fossil and biobased FT-diesel (Framtidsbränslen, 2008). Framtidsbränslen was also one of the many actors participating in the cooperation BioFuel Region, founded in 2003 to focus on cellulose ethanol development in the region around Örnsköldsvik, developed by SSEU/BAFF (Christensen, 2005).

Like Oroboros, Framtidsbränslen supported several trials involving FT-diesel. The company even gained tax exemptions in March 2003. The tax exemption was only available for 10 000 m3 of Paradiesel in 2003, but it stimulated more experiments. The actors running vehicles on Paradiesel included Sundsvall municipality, the forestry company SCA, the construction company Skanska, the harbour Sundsvalls Hamn, and the ferry company Waxholmsbolaget (Framtidsbränslen, 2008).

In 2002 Framtidsbränslen also investigated the feasibility of bio-based FT diesel, financed by the county of Västernorrland and the municipality of Sundsvall. A more elaborate follow-up study was carried from 2004 to 2005. Akzo Nobel, AGA Gas, Sundsvall municipality (Focusera Utveckling AB), Mid Sweden University, Chalmers University of Technology and Umeå University also participated in the project. The R&D programme of the energy authorities, Alternative Fuels, granted partial financing of SEK 0.5 million. Due to severe bottlenecks in the production of syngas from biomass, the recommendation of the feasibility study was to start production of fossil FT-diesel based on the waste gases that were burned by the chemical company Akzo Nobel in Sundsvall. The production would be limited to 5 000 litres a day. Later, when the bio-based technology was mature, the plant could be complemented by a gasifier fit for biomass (Framtidsbränslen, 2008).

In September 2005 the FT-diesel Paradiesel by Framtidsbränslen was introduced on to the market. There were two types marketed - Paradiesel 1, which was a pure Fischer Tropsch diesel based on natural gas, and Paradiesel 5, in which the same Fischer Tropsch fuel included a 5% mix of RME (Framtidsbränslen, 2008). According to Framtidsbränslen, small scale mixes with RME reduce CO_2 emissions by up to 10%, and thus create cleaner fuels. Ecopar, however, argued that a mix with RME would increase dirty emissions compared to the use of pure GTL (Tandberg, 2005; Framtidsbränslen, 2008).

The commercialization of Paradiesel gained an additional stimulation from a tax exemption from September 2006 to December 2008. The exemption was equal to a reduction of about SEK 1.50 per litre for a volume of 5 000 m^3 annually (Framtidsbränslen, 2008). Through the efforts of both Oroboros and Framtidsbränslen, fossil-based FT-diesel became a commercial product in Sweden. As outlined on the website of Ecopar (Ecopar, 2008) the main market was companies using diesel engines in work-related settings, e.g. forest machines, construction work, garbage trucks, to reduce health hazards for employers.

To conclude, the development of synthetic gas fuel markets was mainly related to fossil-based synfuel in vehicle trials. Only in the case of DME was actual bio-based synfuel produced and used. This means that the majority of the synfuel experiments carried out in this period were dominated by the testing of various advanced concepts relating to gasification.

8.4.2. Synfuel SNM analysis, 1997-2010

Synfuels														
Year	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
FT- diesel		Fuel R&D Oroboros			Ecopar production									
					10 vehicles									
					Oroboros pump									
						30 forest machines								
						Other fleets follow								
						Paradiesel Framtidsbränslen								
						4 heavy ehi-cles, 4 lawn movers								
							2 buses							
									Other fleets follow					
DME				Volvo engine R&D										
									Volvo trucks					
					R&D Värnamo plant									
									CHEMREC gas plant/R&D					
										CHEMREC Pilot DME /R&D				

Table 41: Synfuel development, 1997-2010

DME

Network actors	Biofuel	Expectations	Key experiments	Learning	Socio-technical configurations
DME production and use	Municipality of Växjö, Volvo, universities, Chemrec gasification plant, pulp and paper industry. Värnamo withdrew at the end of the period. Alignment initially weak, but increased with time.	As an impending cheap and highly environmentally friendly fuel.	While southern experiment failed, the Chemrec pilot was realized in 2006 as well as Volvo trucks on DME.	Mainly technical lessons as a result of realized pilot production technology and engine technology. Reflexive learning indicated by Chemrec, which did not define end product.	Production R&D niche and very small heavy vehicle niche.

FT-diesel

Network actors	Biofuel	Expectations	Key experiments	Learning	Socio-technical configurations
Universities, Companies (Framtidsbränslen, Oroborås/Ecopar), no bio-FT production actors.	FT-diesel production and use	As an impending cheap and highly environmentally friendly fuel; alternative fit with conventional infrastructure and engine technology.	Mainly focus on fossil-based FT diesel use, wait on scientists in gasification field before investment in production	Driving on fossil FT diesel works	Remain an R&D niche.

Interest in synthetic gas fuels returned in this period, which led to the creation of networks linked to each synfuel – of which the DME and the FT networks realized niche experiments. The DME network had two innovation clusters. First, a southern cluster led by Växjö municipality, in collaboration with its energy companies, the gasification plant in Värnamo and Volvo, which did not manage to get the fuel experiments going due to limited interest from industry in matching the government funds available. Second, a northern cluster in Piteå led by the gasification company Chemrec in collaboration with the paper and pulp industry, Volvo, universities and research institutes and various European actors. By means of funding from the EU a pilot was constructed in 2006. A larger, demonstration plant was realized in 2012. The FT network was driven by two companies, Framtidsbränslen and Oroborås, that ran field trials with fossil FT-diesel in conventional diesel vehicle fleets. The fossil nature of the fuel and fit in diesel engines meant that regime actors were part of the network. The FT network showed very limited production ambitions. The lack of large industrial actors interested in fuel production seems to have been a barrier to development in both the Växjö DME and the FT-diesel projects. In contrast, the relative success of Chemrec can be related to the broad actor network involving strong actors in both the user and the production domains.

The *expectation* for all synthetic fuels was that they could be produced in a highly energy efficient way and from a greater variety of bio-based feedstock compared to other biofuels. This meant that they were seen as more environmentally friendly and cheaper alternative fuels in the long term. According to FT-diesel actors, the mature natural gas based technology also had environmental benefits which with time could bridge the period until the more environmentally friendly bio based FT diesel matured. Unlike DME, FT-diesel engines or infrastructure did not need adaptation. The lessons from the various experiments enforced the positive expectation of both FT-diesel and DME. In the relatively well known FT-diesel case, only limited learning was necessary to demonstrate the good engine fit and the environmental benefits of fossil FT-diesel. However, the lessons of the Chemrec DME pilot process indicated a technical breakthrough, being the first bio DME production achieved. Moreover, in comparison with other advanced biomass to liquid processes it was evaluated as the most energy and cost efficient.

Alongside wide actor support and positive expectations, the Chemrec process attracted large scale EU, government and private financing. The result was an emerging technical niche with a working demonstration plant and a field trial with a few DME trucks with support from a limited distribution infrastructure in 2012. The fossil FT-diesel had only a limited network and biofuel development ambitions, which corresponded with the development of a very limited vehicle market niche. In comparison with the large market share of other biofuels, the synthetic fuels were just a niche at the periphery.

8.4.3. Synfuel discourse development, 1997-2010

Synthetic fuels are liquid fuels based on fossil or bio-based feedstock. Some of them are produced based on natural gas, such as the methanol vehicle fuel used in the Swedish experiments in the 1970s and 1980s, while others are produced by means of a gasification route in which feedstocks such as coal or biomass are used. Like the early methanol discourse, synthetic fuel actors in this period saw the biomass gasification route as the ideal. In addition to methanol, two other fuels were promoted. First, Fischer Tropsch diesel, which was a known coal-based technology exploited in Germany during the Second World War and to a large extent in South Africa to date (Wikipedia, 2011). Second, Dimethyl Ether, which was a newer technology developed in Denmark (Sandén & Jonasson, 2005).

Together, methanol, Fischer Tropsch diesel and DME became part of a general synthetic gas fuel, or syngas fuel, discourse that appeared in the late 1990s. The interest in further syngas fuels was expressed in the context of increasingly organized criticism of ethanol which appeared at the political level under the lead of the Swedish Road Administration (Miljörapporten, 1999c). The criticism was linked to the increasing government funds awarded for ethanol development as a result of the expanding environmental discourse, and CO_2 reductions in particular, in the 1990s (Sandén & Jonasson, 2005; Kommunikationskommittén, 1997: appendix).

In a report by the Swedish Road Administration, Hådell (2001) argued that 'methanol and DME show a 32-39% better [energy] yield compared to ethanol when produced from cellulose, and most [research findings] show that ethanol will be more expensive to produce' (Hådell, 2001: 15, translation by the author). In addition, Hådell argued that the ethanol technology was not as flexible as the syngas technology with regard to feedstock and fuel output. This meant that the supply of raw materials for ethanol production was limited and that ethanol was not an equally suitable stepping stone to future hydrogen-based transport fuel. The report concluded that more attention should be given to the ability to develop biofuel options such as methanol, DME, Fischer-Tropsch and Hydrogen (Hådell, 2001).

In 2004 the Swedish Road Administration gathered a coalition of three additional public authorities - VINNOVA, the Swedish Energy Authority and the EPA. The initial aim of this coalition was to lobby against the continued tax exemption for crop ethanol and RME, in order to create more funds for long-term options such as syngas based biofuels (Samuelsson, 2004e). With regard to biogas, the criticism was not equally strong since it was considered to be more environmentally friendly. However, the limited ability of biogas to expand beyond a niche fuel meant that it was not considered to be a relevant fuel option (Hådell, 2001). Eventually, this lobby shifted its focus to two syngas fuels, DME and Fischer-Tropsch. It started to criticize cellulose ethanol as well as RME and crop ethanol. The lobby repeated Hådell's previous arguments that syngas fuel was a more sustainable option due to its better cost efficiency, feedstock flexibility and match with long term solutions such as hydrogen (Hådell, 2005; Samuelsson, 2005b; Samuelsson, 2004e; Samuelsson, 2005b). The shape of the syngas fuel discourse meant that it opposed the wider bridging argument that was introduced by many first-generation biofuel and cellulose ethanol actors. Instead, an alternative bridging argument was presented in which syngas fuels would be followed up by hydrogen. Like the early methanol discourse, single syngas fuel proponents (Framtidsbränslen, 2008; Ecopar, 2008) expanded these bridging arguments with the use of natural gas based synfuel as a preparatory stage before the syngas processing technology was sufficiently mature to be exploited on a large scale. They also argued that the natural gas-based fuel was more environmentally friendly compared to conventional fossil diesel. By these means not only the bio-based, but also the fossil-based syngas fuels showed an attempt to link up with the environmental discourse. The establishment and growth of the syngas fuel discourse throughout this period indicates that the embedding in the environmental discourse was becoming reality.

The growth of the syngas fuel discourse was thanks not only to the work of powerful syngas proponents, but also to contextual developments. An example of this was the increased competition on the renewable energy market around the turn of the century, which made the gasification technology too expensive and less attractive to invest in. Consequently, unemployed researchers in the field of biomass gasification to energy were attracted to vehicle fuel projects based on the same technology. Some of the researchers joined DME projects with energy companies; others started their own initiatives, aided by the increased interest in CO_2 reduction in the transport sector. One example of the latter was the gasification technology company Chemrec experimenting with syngas production from black liquor, a waste material from the paper and pulp industry (Fallde et al., 2007).

An additional factor that contributed to the further expansion of the syngas discourse from the mid-2000s was the international anti-biofuel lobby. This lobby criticized crop-based biofuel production for competing with food production, contributing to the increase in CO_2 emissions, reducing biodiversity and having negative socio-economic effects on communities in the South. The actors giving light to these problems in Sweden (Kågesson, 2005; Azar, 2006a) saw second-generation fuels such as cellulose ethanol and synfuels as a potential remedy to these problems while still aiding the CO_2 reductions in the transport sector. Consequently, they lobbied for increased funding to second-generation fuels (ibid.). Increased support was also gained from the EU level in 2009, when the anti-biofuel discourse led to a revised Biofuel Directive (EC, 2009) in which the 10% biofuel implementation target for 2020 prioritized advanced transport fuel options, such as synfuels based on waste, residues and non-food cellulose materials. They were to be counted double conventional biofuels (ibid.), a policy measure that is likely to stimulate Swedish synfuel discourse development.

Alongside the general syngas fuel discourse, smaller sub discourses appeared for each synfuel. In the case of methanol, it was a forerunner to the general syngas fuel discourse. When the methanol discourse lost popularity in the late 1980s, some methanol proponents started the company Ecotraffic while others moved to the many research institutes focusing on gasification research (Sandén & Jonasson, 2005). Ecotraffic made an attempt to revive the methanol discourse in the early 1990s, but without success (Carlsson & Molin, 1991). A sign that methanol was not forgotten was the reference to alcohol fuels and the inclusion of methanol in the many reports discussing and evaluating biofuels throughout the 1990s (e.g. Ahlvik & Brandberg, 2002; Alternativbränsleutredningen, 1996; Brandberg & Sävbark, 1994; Månsson, 1998). The proponents of a rather weak methanol discourse in the late 1990s were the environmental debater Björn Gillberg and Ecotraffic. They tried to gain support for methanol by arguing how much better methanol was compared to ethanol, which takes us back to the debate between these fuels in the 1980s and serves as a starting point for the general syngas discourse described above. The most common argument used to promote methanol was that it had higher fuel efficiency than ethanol. Other arguments why methanol should be exploited instead of ethanol were lower demand for cultivation acreage, an increasingly flexible feedstock and lower production costs. A combined production of methanol with heat and energy was said to be most cost-efficient, since the output of products could be adjusted by season (Miljörapporten, 1998a; Miljörapporten, 1998c; Samuelsson, 2004f).

While there was no real anti-methanol lobby, the general preference regarding alcohol fuels was cellulose ethanol since the technology was considered to be closer to commercialization (Miljörapporten, 1998e).While ethanol proponents tried to build bridges between the two fuels, as is outlined in the BAFF aims in the ethanol section above, methanol actors rejected the offer. Instead they continued to lobby against ethanol in collaboration with other syngas fuels. Eventually, as is mentioned above, interest in other syngas fuels took over from interest in methanol.

Unlike methanol, DME gained increasingly more support over time. In the late 1990s, Växjö municipality started promoting DME as a means to reach its municipal ambition to become independent of fossil fuels. The municipality presented DME as a suitable fuel due to its particularly high efficiency and low emissions levels (Fallde et al., 2007). Similar arguments of high performance and low emissions were referred to by Volvo when it decided to develop a tailor made heavy vehicle engine for DME use (Månsson, 1998). Together, Volvo and Växjö municipality were the main DME coalition actors, lobbying for recognition and financial support for a DME production plant and heavy vehicle developed by Volvo (Fallde et al., 2007). The production of the first bio DME by the gasification company Chemrec in 2006 (Lindblom & Landälv, 2007) is likely to have contributed to the growing support for this particular syngas fuel.

The third synfuel alternative, which emerged at the end of the 1990s, was Fischer Tropsch diesel. FT-diesel was argued to beneficial since it could be used in conventional diesel engines and in a mix with diesel, something that was not possible with DME. It was argued to be a cleaner fuel when based on natural gas, and even more so once based on bio-based syngas (Framtidsbränslen, 2008; Ecopar, 2008). Unlike the other synfuels, the actors promoting FT diesel were not also driving the development of a bio-based syngas fuel. One potential reason for this was the already successful market implementation of fossil-based FT diesel.

All in all, the syngas biofuel discourse was only a sideline to general biofuel discourse developments. While they objected to other biofuels, ethanol in particular, this did not stop ethanol actors seeking collaboration with synfuel actors. Like the collaboration sought by cellulose ethanol actors with methanol, ethanol actors supported the Fischer Tropsch company Framtidsbränslen in the Biofuel Region. While the ethanol coalition failed to start a cooperation on methanol, it was increasingly successful in its cooperation with the Fischer Tropsch actors (Christensen, 2005). This indicates that neither the synfuel coalition nor their bridging scenario were powerful enough to be seen as a threat to ethanol and the wider biofuel discourse.

8.4.4. Synfuel discourse analysis, 1997-2010

Policy	Level	Year	Type	Size SEK	Explanation
DME					
Växjö/ Värnamo DME pilot	Municipality	1996-2004	Feasibility studies DME production	KFB Biofuel programme	Various feasibility studies and application for DME pilot. Failed to get funding.
Volvo DME engine	Industry	Early 2000s-	R&D	?	2004 a DME truck was developed after years of research. Tests started 2005.
Chemrec DME pilot	Industry	2004-	Production DME	BLG supplied funds	By means of the EU RENEW project, a DME pilot plant, with potential to produce methanol as well, was realized based on the Chemrec black liquor process in 2006.
BioDME project, demon-stration plant	Industry	2009-	Production DME	Total cost SEK 150 million. EU and government granted funds	2009 construction of DME demo plant starts. Plans involve the construction of a DME system, such as heavy vehicles and DME pumps.
FT-diesel					
Ecopar	Industry	1998-1999	R&D		Oroboros starts environmental consulting and research.
	Industry, university	1999-	R&D	?	1999 fuel trials in laboratory. Result in technical specification for fuel production.
Holm's farm field trial fossil Ecopar	Industry	2000-2001	Field trial	?	2000 field trial with Ecopar in six vehicles and one loader. Additional 5 cars and fuel distribution in 2001.
Market intro-duction of fossil Ecopar	Industry	2002-	Field trials	Potential tax exemption	Market introduction of Oroboros Ecopar. This facilitated trials with fleets such as forest and construction companies and municipalities.
Fossil paradiesel	Industry, municipality, government	2002-2004	Field trial	Tax exemption for 10 000m^3 in 2003	Field trials with Paradiesel by Framtidsbränslen. Especially tax exemption triggered trials by Sundsvall municipality, the forestry company SCA, the construction company Skanska, the Sundsvalls harbour and the ferry company Waxholmsbolaget.
Bio-based Paradiesel	Municipality, industry	2002, 2004-2005	R&D	Financed by county of Västernorrland, Sundsvall municipality, and SEK 0.5 million by government	Framtidsbränslen feasibility studies of bio-based FT-diesel together with universities, industry and local authorities. Result: syngas from biomass not yet feasible.
Market intro fossil Paradiesel	Industry	2005-	Field trial	Tax exemption 15 000 m^3 for 2006-2008.	2005 market introduction of Paradiesel followed by continued and expanded experimentation.

Table 42: Syngas fuel policy developments, 1997-2010

Biofuel	Discourse	Mobilization/ impact of wider discourses, events and policies.	Discourse coalition	Target audience	Key activities, strategies	Resulting space/ policy creation or disruption
FT-diesel and DME production and use	Best future fuel due to potentially high CO_2 reductions, relatively low costs, ability to use different feedstocks and contribute to regional development. Natural gas based synfuels as a bridging technology with environmental benefits. FT diesel particular fit with engine technology, while DME has better performance and environmental benefits.	Embedding particularly in global environment discourse, but also regional development discourse	National authorities led by Swedish Road Administration. Lobby for individual fuels: Ecotraffic, municipality Växjö, Chemrec, Volvo, Framtidsbränslen.	Government and wider public	Lobbying in national and local policy arenas, use of scientific reports, media and campaigns. Opportunistic strategies not coherent across coalition. While national authorities supported the anti-biofuel discourse and discredited conventional biofuels, FT-diesel actors supported biofuel discourse.	Small-scale tax exemptions for FT-diesel vehicles. R&D subsidies for gasification and DME production, which led to a DME pilot plant and heavy vehicle engines. No visible policy institutionalization

Despite their novel and marginal position in comparison to other biofuel discourses, the discourse on syngas fuels stated that it was the best alternative fuel for the future. This was related to expectations of their high CO_2 emissions reductions, affordable production costs, and ability to use a wide variety of biomass and contribution to regional development. Natural gas-based synfuels were seen as a bridging technology with environmental benefits, in a similar way to natural gas-based methanol in the early 1980s. In addition, synfuels provided a bridge to more advanced fuels such as hydrogen. The interest in using natural gas was particularly true in the FT discourse. FT diesel was also viewed as particularly good due to its fit with current engine technology, while DME was seen as one of the better alternatives from an emissions reduction and performance point of view. As is indicated in the discussion of the discourses, embedding was particularly successful in the global environment discourse, but it was also sought in the regional development discourse. Embedding was also sought in the anti-biofuel discourse, but this did not prevent certain linkages with the biofuel discourse as well. An external factor that contributed to the development of this discourse was increased competition on the electricity market, which attracted syngas actors and investment in the biofuel sector.

There was a common synfuel coalition made up of various national authorities under the lead of the Swedish Road Administration and scientists. In addition, there were individual lobbying actors for each syngas fuel, such as the consultant company Ecotraffic, Växjö municipality, the gasification company Chemrec, Volvo and Framtidsbränslen. However, coalition coherence was weak since collaboration across the individual synfuel coalitions or between the general and individual synfuel coalitions was more or less non-existent. This is indicated by the fact that the general synfuel coalition supported and sought embedding in the anti-biofuel discourse by criticizing ethanol, while the FT-diesel coalition sought embedding in the biofuel discourse by cooperating with ethanol actors in building the Biofuel Region. Lobbying by the general synfuel coalition was carried out in the policy arena and in scientific reports to gain support from the government and reduce support for conventional biofuels. The individual synfuel actors were directing their lobbying activities to the government, but also to the local authorities and the general public to gain support for their fuels. Measures used were scientific reports, public campaigns and articles in the media. Their opportunism and lack of collaboration are likely to be related to the emergent nature of these discourses.

Unlike many other biofuels, synfuels did not face any serious discourse resistance. As is indicated in Table 42, support for synfuel was mainly small-scale tax exemptions for FT-diesel trials and R&D subsidies for the development of the gasification process, DME production and heavy vehicle engines. While this funding led to the marketing of fossil FT-diesel and the construction of a DME pilot plant and engine, there was no visible institutionalization. Increased support and discourse stability might, however, have been expected after the publication of the 2009 EU Biofuel Directive, which prioritized advanced biofuels.

8.5. GENERAL BIOFUEL AND ANTI-BIOFUEL DISCOURSES, 1990-2010

This section presents a discourse analysis of the general biofuel discourse and an anti-biofuel discourse based on the different biofuel policy processes in the period 1990-2010 outlined in chapters 7 and 8.

8.5.1. Conventional biofuel discourse and anti-biofuel discourse development, 1990-2010

Policy	Governance level	Year	Type	Size SEK	Explanation
'Green folkhem'	Government	1996-2005	Vision	?	Repeated statements that Sweden should lead environmental development.
Temporary tax exemptions	EU, Government	1995-2001	Field trials	Approx. SEK 80 million	All biofuels trials were granted prior to 1997. 1997-1998 no new tax exemptions. 1999-2001 only Agrietanol.
		2002	Field trials	SEK 250 million	Selected projects granted, excluding ethanol.
		2003	Field trials	SEK 450 million	Increased exemptions, ethanol included.
		2004-2013	Field trials	SEK 800 million in 2004 to SEK 2.25 billion in 2009	General, but time limited tax exemptions to all biofuels thanks to EU Biofuel Directive.
LIP	Government, Municipality	1997-2002	Subsidy	SEK 150 million government + SEK 600 million matching	Local Investment Programme (LIP) supported biogas and a few ethanol projects.
EU policy	EU	2003-		?	Directive 2% biofuel implementation 2005, 5.75% in 2010 and 10% in 2020. The 10% target set in 2009 gave priority to advanced biofuels.
Biofuel policy	Government	2004		?	Sweden sets 3% as 2005 target, but it was not reached.
Biofuel vehicles	government	2000-2006	Field trial	?	Successive increases in subsidies for renewable leasing vehicles. Biogas gained more subsidies than ethanol.
Fuel mix standard	EU, government	2000-	regulation	?	2000 onwards, the EU limited the ethanol mix in gasoline to 5%. E10 and E20 projects withdrawn.
Clean Vehicles	EU, municipalities	2003-	regulation	?	Local incentives for biofuel vehicles, such as free parking, exemption from congestion fees in major cities.
Fossil free	Government	2005	statement	?	Prime minister states that Sweden should become independent of oil by 2020.

Pump law	Government	2005-	regulation	?	2005 pump law leads to successive increase in pure biofuel distribution, mainly E85.
Clean vehicle premium	Government	2007-2009	Subsidy	Budget: SEK 815 million	10 000 SEK rebate is given to private individuals buying a biofuel vehicle or other 'clean' vehicle.
Renewable Energy Directive (RED)	EU	2009	regulation	?	Target of 10% renewable fuels by 2020. Prescribing sustainable criteria and double counting of biofuels based on waste and non-food materials. Proposal 2008, implemented 2009.

Table 43: General biofuel policy development, 1998-2010

8.5.2. Conventional biofuel discourse analysis, 1990-2010

Biofuel	**Discourse**	**Mobilization/ impact of wider discourses, events and policies.**	**Discourse coalition**	**Target audience**	**Key activities, strategies**	**Resulting space/policy creation or disruption**
Conventional and advanced ethanol production, and use as high and low blend in vehicles	Early 1990s: means to aid farmer livelihoods, reduce local and global emissions, reduce oil dependency. Late 1990s onwards: global environmental emission reduction and regional development increasingly stressed as well as the suitability of conventional biofuels in the short term and advanced in the long term.	Embedding in local and global environmental discourse, farmer livelihood/ regional development discourse, and self-sufficiency discourse. Events such as the three-party agreement and the EU Biofuel directive aid discourse developments.	Government, ethanol and RME proponents	Lobbyinitially at EU and later national level	Lobbying expressed in various policy reports and arenas at the national and EU levels as well as through the media and scientific publications. Strategies used argue the need for all biofuels in different times and fields, conventional and advanced, and the need to implement to keep Sweden's leading environmental status.	Various subsidy and tax measures that paused in 1997-2002 and were reduced in the late 2000s

A general biofuel discourse emerged in the early 1990s in which conventional biofuel in particular was seen as a means to aid farmers' livelihoods and reduce both local and global emissions in the transport sector. A less prominent part of the discourse was the idea of reduced dependency on politically unstable oil producing countries. From the mid-1990s, conventional biofuel was increasingly seen as the solution to the reduction of global emissions and the stimulation of regional economic development in the short term, while advanced biofuels were considered to be the best solution in the long term. The three-party agreement stimulated the initial development of the discourse, and the preparation and implementation of the EU Biofuel Directive was a second external stimulus. The discourse was embedded in the environmental discourse and the farmer livelihood discourse, which at a later stage gained a regional development focus.

The reference to reduced oil dependency was related to a broader self-sufficiency discourse. The main actor behind this discourse was the Swedish government. The EU also supported biofuels, but it was initially seen as a barrier since it did not allow the general tax exemptions in force in Sweden. This is reflected in a quote by the Swedish government: 'the [EU] pilot project law should be practiced in a way that prevents any change in the way motor alcohols and vegetable fuels were taxed before joining the European Union'. In the mid-2000s, however, the EU stimulated governmental biofuel protection as a result of the Biofuel Directive. Additional forces behind the biofuel coalition from the late 1990s onwards were the ethanol and later the RME coalitions. A quote reflecting broad biofuel support in the 2000s was the argument of a leading ethanol advocate, the party leader of the Centre Party: 'The Centre Party does not advocate one [bio-] fuel over the other, even if I am driving an ethanol car myself'. Lobbying took place in various policy reports and arenas at the national and the EU levels as well as through media and scientific publications. Arguments in which conventional and advanced biofuels were linked, as well as the argument that Sweden was a leader in environmental development, were strategically used to legitimize biofuel implementation. Generally, when high status actors such as the EU and the government were backing the discourse, they contributed to discourse stability.

The resulting biofuel support of this discourse was already visible in the early 1990s with the implementation of general biofuel tax exemptions and the first biofuel subsidy programme – the Biofuel Programme. Due to adjustments to EU policy and emerging criticism from a competing synfuel discourse, protection became restricted and tax exemptions were scarce between 1997 and 2002. A new EU biofuel policy in 2003 stimulated high biofuel protection, involving general tax exemptions, subsidies and supportive regulations. However, the synfuel lobby became embedded in a larger international anti-biofuel discourse that grew stronger in the late 2000s and posed a serious threat to conventional crop-based biofuels.

8.5.3. Anti-biofuel discourse analysis, late 1990s to 2010

Biofuel	Discourse	Mobilization/ impact of wider discourses, events and policies.	Discourse coalition	Target audience	Key activities, strategies	Resulting space/policy creation or disruption
Anti-biofuel, certain acceptance of advanced alternatives	Late 1990s: only limited or no emission reductions from conventional biofuels. Mid-2000s onwards: conventional biofuels lead to more emissions compared to fossil fuels, competition with foods, biodiversity loss and exploitation of labour in developing countries.	Embedding in environmental discourse, human rights discourse. External events: food scarcity and the food versus fuel debate.	Synfuel coalition, scientists, international anti-biofuel proponents (NGOs, environmental organizations, politicians)	Government and wider public.	Lobbying expressed in various policy arenas at the national and international levels, in the media and in scientific publications	Prevention of EU obligatory biofuel implementation, development of sustainability criteria and slow down of biofuel implementation.

The anti-biofuel discourse introduced a negative perspective on conventional crop-based biofuels. Initially, at the turn of the century, the discourse highlighted the limited or absence of emissions reductions of crop-based biofuels. In the mid- to late 2000s, crop-based biofuels were argued to lead to more emissions compared to fossil fuels, competition with food production, the degradation of biodiversity, to endanger food security and the exploitation of labour in developing countries. Criticism was also directed towards advanced fuels such as cellulose ethanol. Like the biofuel discourses, this discourse attempted to embed in the environmental discourse by referring to the need to reduce local and global emissions by means other than conventional biofuels. The references to food security and exploitation of labour were triggered by the food crisis of 2007, which indicates a linkage of the anti-biofuel discourse to a wider human rights and solidarity discourse.

Initially, the main promoters of this discourse were the Swedish syngas fuel coalition, national politicians and scientists. One example of the initial arguments against biofuel protection came from the Ministry of Finance that with the rejection of general biofuel tax exemptions argued that: 'Old known ethanol technology will not be included in the much disputed pilot project exemptions. We will not hold the ethanol industry under their arms'. At a later stage, the coalition was strengthened by wider international anti-biofuel sentiments driven by international politicians, environmental organizations and other NGOs. This meant that the coalition expanded and increased in variety over time. The lobbying used political arenas at the national and international levels, scientific documents and most of all the media to collect support from the government and the wider public. Both the food versus fuel debate, which increased the coherence of the coalition actors and the ability of environmental organizations and other political actors to influence the public debate, contributed to the increased popularity of this discourse in the mid- to late 2000s.

Although a halt to biofuel development was not achieved by means of this discourse, the termination of the EU's plans to impose obligatory biofuel implementation targets, the development of criteria for sustainable biofuel development and increased priority for advanced biofuels and other fuel solutions in the transport sector indicate certain policy influence.

8.6. CONCLUSIONS: BIOFUEL DEVELOPMENT, 1998-2010

This section draws conclusions on all biofuel developments in the period 1998-2010 from both an SNM and a discourse perspective.

8.6.1. Biofuel SNM conclusions

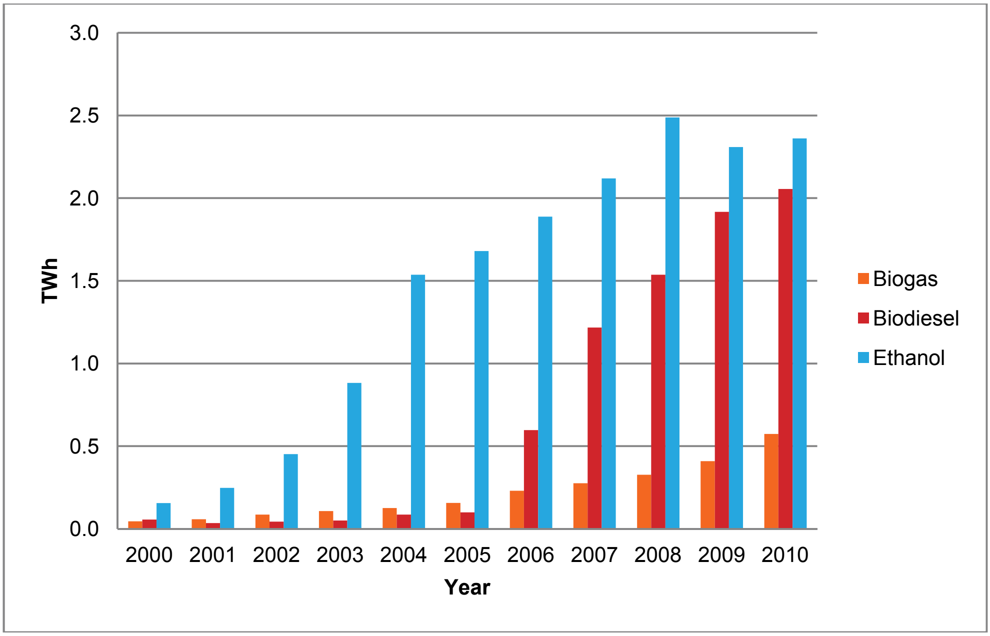

Figure 15: Use of renewable motor fuels, 2000-2010, expressed in TWh.
Source: Statistics Sweden, the Swedish Energy Agency and the Swedish Gas Association.

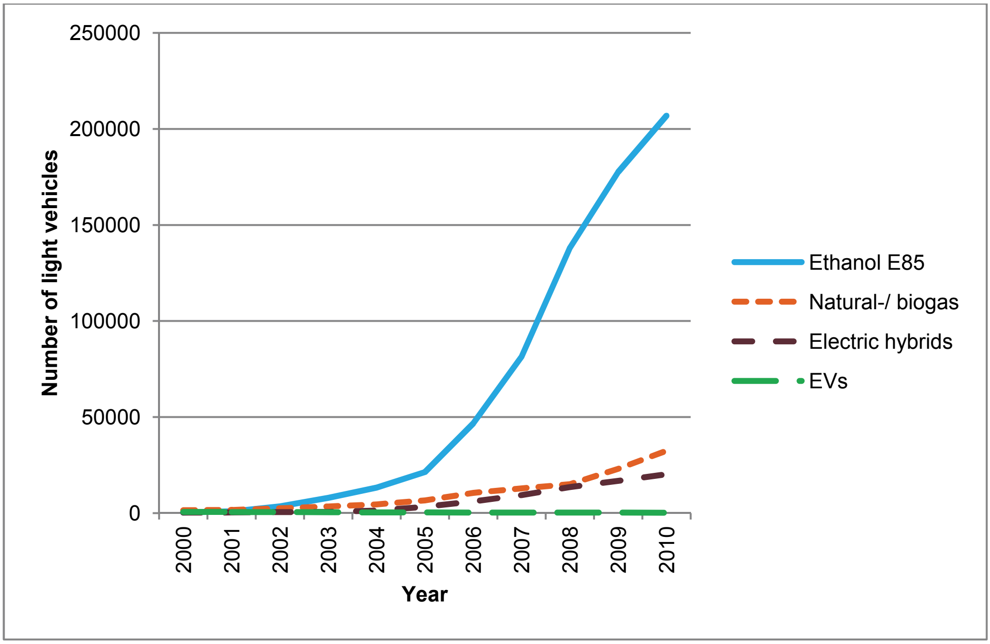

Figure 16: Number of light alternative vehicles, 2003-2010

Source: for 2000-2008 www.miljofordon.se and for 2009-2010 (Pädam et al., 2010; Larsson & Karlsson, 2011)

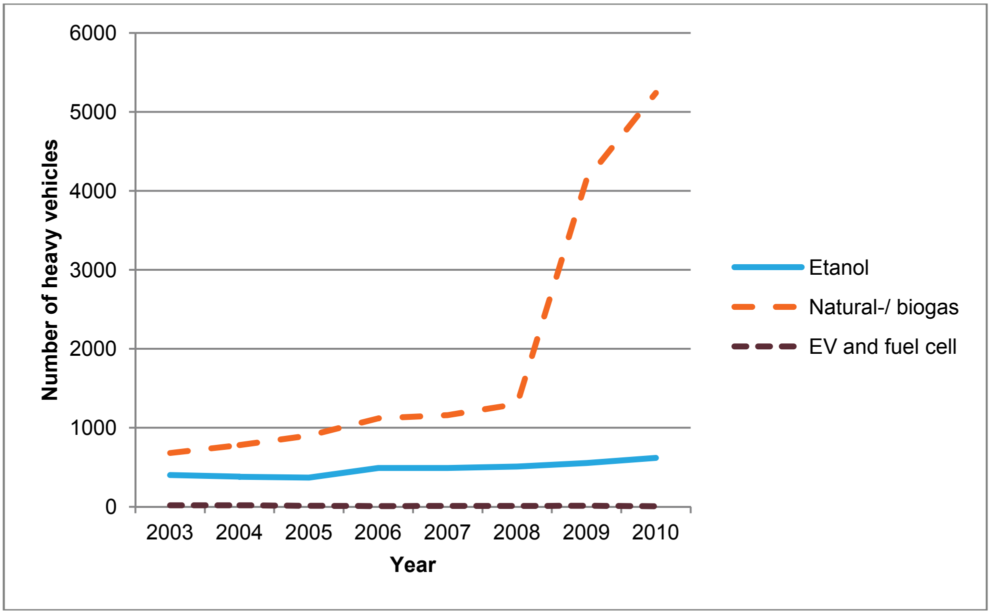

Figure 17: Number of heavy alternative fuel vehicles, 2003-2010

Source: for 2000-2008 www.miljofordon.se and for 2009-2010 (Pädam et al., 2010; Larsson & Karlsson, 2011)

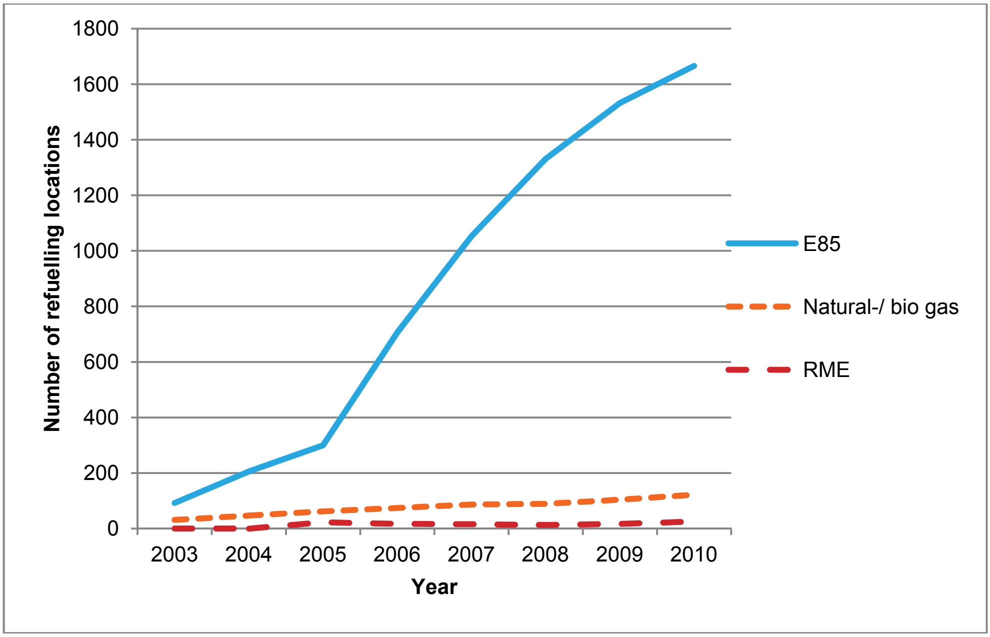

Figure 18: Number of public filling stations, 2003-2010
Source: Swedish Petrolium and Biofuel Institute

Figure 15 shows that biofuel use expanded dramatically in this period, stimulated by internal niche processes and external events such as EU biofuel policy and increased government incentives. Three biofuels were particularly successful. Of these fuels, ethanol was still the largest niche, followed by RME and biogas. While all these fuels had market niches, the pure ethanol and biogas market niches could be considered more stable since they involved large scale socio-technical adaptation and financial investments. That was not the case for low blend biofuels, such as RME, which society could abandon more easily. In comparison to the conventional biofuel niche expansion, the development of advanced biofuels was limited. Cellulose ethanol was demonstrated in 2004, but lost support towards the end of this period. Instead, syngas fuels regained attention and developed a few field experiments.

Consistent with Strategic Niche Management theory, a high degree of niche development and stability went hand in hand with ever more expanding and aligned networks, positive and realistic expectations and learning that linked a variety of lessons. Compared to the previous period, municipalities and other local authorities were still important actors, but mainly in the biofuel networks that supported biofuel vehicles. In the case of RME low blend fuel, oil distribution companies were the main actors.

Like the previous periods, increased government funding went hand in hand with niche development. Increased niche stabilization is reflected in the increased acceptance of and support for the expanding biofuel market niche by regime actors such as fossil fuel distributors, vehicle producers and natural gas actors.

8.6.2. Biofuel discourse conclusions

This period presents continued positive biofuel discourse developments, in which ethanol still enjoys a dominant position. Several discourse development patterns can be identified.

One prominent pattern is the development of a general biofuel discourse. Emergent features of this discourse were indicated at the policy level in the previous period. In this period, the discourse evolves into a biofuel bridging scenario, in which implementation of conventional fuels is promoted until more advanced biofuel options are sufficiently mature. The similarity with the ethanol bridging scenario is not a coincidence, since the ethanol coalition was the main promoter of this discourse. External events such as the EU biofuel policy contributed to the increased stability of this discourse

The RME discourse became visible in this period and increased in stability thanks to its active embedding in the biofuel discourse. However, the discourse remained weak and limited to low blends alone due to continued criticisms.

The biogas discourse was not embedded in the biofuel discourse, but it did not criticize it either which meant that it profited from some of its developments. The natural gas discourse was seen as a bridging technology to further biogas. In the critique of biogas as a niche fuels, syngas was presented as an option for the future. Interest from syngas actors, however, was not demonstrated.

The synfuel discourse of this period focused on diesel fuels instead of methanol. The discourse indicates yet another development pattern focusing on synfuels alone. In contrast to the friendly relations between biogas and the biofuel discourse, the synfuel discourse was strongly opposed to the biofuel discourse. Harsh criticism of ethanol and RME made the synfuel discourse a forerunner to a general anti-biofuel discourse with the support of both national and international coalition actors. However, that some synfuel actors sought support from ethanol actors and embedding in the biofuel discourse indicates opportunism and a relatively weak discourse.

The peak of the anti-biofuel discourse in 2007 had a negative impact on the development of the RME and ethanol discourses and steered general biofuel discourse development towards increasing the priority of advanced biofuels. Despite the weakening of the discourse, the strong financial protection of conventional biofuels continued, which indicates particular discourse strength.

9. CONCLUSIONS

9.1. INTRODUCTION

This chapter draws conclusions based on the research questions posed in the introduction and the two biofuel case studies presented in the above chapters. I used two analytical frameworks to answer the main question: 'How can we explain differences in biofuel niche development in Sweden and the Netherlands in the period 1970-2010?'. First, the SNM framework to analyse the development of internal niche processes and the biofuel developments (socio-technical configurations) they have resulted in. Second, a discourse framework to analyse the policy process and the policy instruments (resulting space) that have contributed to or hampered the biofuel development process.

I start by presenting an SNM and discourse analyses of the Dutch and Swedish cases for the entire period (1970-2010), based on the analysis in the empirical chapters 2 to 8. I then compare the case studies to answer the main research question regarding the differences in Swedish and Dutch biofuel development. I close the chapter with a concluding discussion involving theoretical reflections and ideas for a future research agenda.

9.2. BIOFUEL DEVELOPMENT IN THE NETHERLANDS, 1990-2010

In the Netherlands, biofuel development had a slow start. Actual biofuel use did not show in the statistics until the early 2000s (see Figure 19) despite repeated biofuel initiatives from the early 1990s onwards. Some of the explanations for slow biofuel implementation are rather obvious and related to the limited access to biomass resources and the dominant position of the petrochemical industry. More elaborate explanations for this biofuel development trajectory have been identified by means of an SNM and discourse analysis. After outlining the main Dutch biofuel and policy developments from 1990 to 2010, the SNM and discourse analyses of these developments are summarized and conclusions drawn.

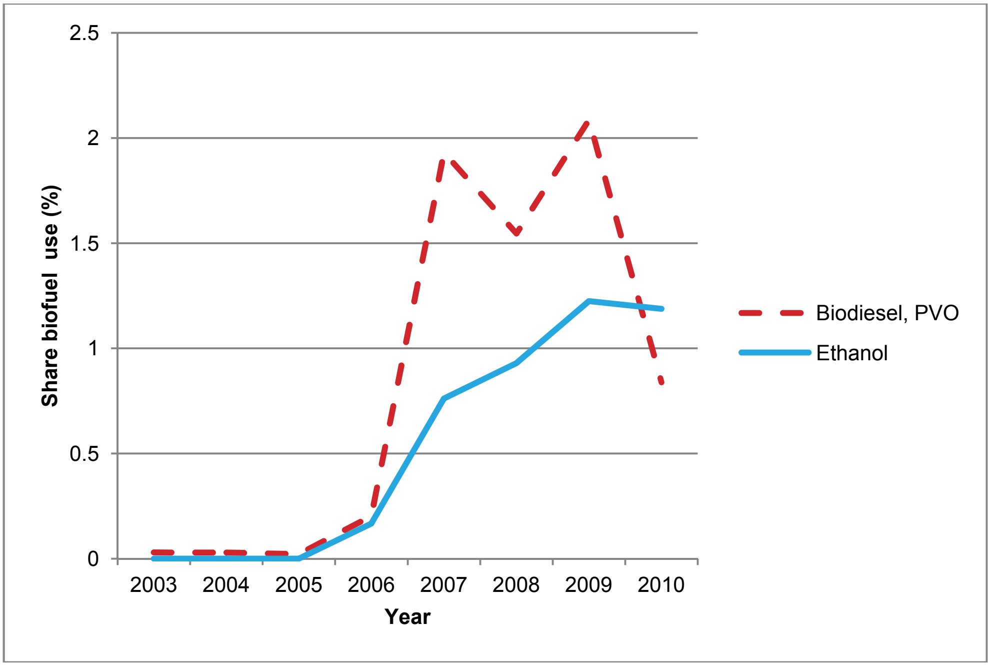

Figure 19: Share of ethanol, biodiesel and PVO in use of total road transport fuels, 2003-2010[94]
Source: Statistics Netherlands

[94] The share of biofuel use has been calculated based on the energy content of the biofuels and total vehicle fuels (alternative and fossil) used in the road transport sector.

Year	Biofuel-related policy events
1992	EU Common Agricultural Policy reform, allowing for temporary biofuel tax exemptions First national biofuel tax exemption granted for two ethanol buses.
1994	1994-1998: National policy allowing for short term conventional biofuel tax exemptions for single field experiments.
1995	1995-2010: Advanced biofuels gain increased recognition and funding from various bioenergy support programmes (e.g. EET, EOS).
1997	CO_2 reduction plan implemented. Government support granted for large-scale ethanol project, but it fails to start 1998.
1998	1998-2001: Absence of temporary conventional biofuel tax exemption.
2001	EU Biofuel Directive proposal presented. 2001-2003: GAVE programme for advanced biofuel development only. Programme ends early.
2002	2002-2010 Temporary biofuel tax exemptions are granted; slightly longer term than previously but strictly limited to selected PVO and biodiesel trials.
2003	EU Biofuel Directive published, setting indicative biofuel targets for 2005 and 2010. EU Fuel Tax Directive permits general biofuel tax exemptions. From 2003: GAVE support programme assisting government and stakeholders to meet EU policy targets.
2004	Government announcement of financial stimulus for conventional biofuels in future. Development of sustainable criteria begins.
2006	One-year general biofuel tax exemption for 2006 to facilitate introduction of obligatory biofuel targets from 2007. 2006-2008: Innovative Biofuels programme for the development and implementation of advanced biofuels, ends early.
2007	2007-2008: International food crises. EU proposes obligatory biofuel implementation target of 10% in 2020. Obligatory biofuel distribution targets for fuel distributors, in order to meet EU targets.
2008	EU plan for obligatory implementation target withdrawn. Obligatory national biofuel implementation targets reduced. 2008-2009: Subsidy for alternative fuel stations (TAB) stimulates ethanol pumps for FFVs.
2009	EU Renewable Energy Directive (RED) promotes implementation of advanced biofuels and alternative fuels, provided that sustainable criteria are met. Biofuel implementation targets include double counting biofuel measure for particularly sustainable and advanced biofuels, according to EU RED.
2011	Implementation of sustainable criteria according to EU RED.

Table 44: Main Dutch biofuel policy events, 1980-2011

9.2.1. Dutch biofuel policy and technology development

The policy developments described in Table 44 indicate the implementation of short-term and small-scale tax exemptions for single ethanol and biodiesel field experiments in the 1990s. At the same time, advanced biofuel process technologies gained R&D funds through bioenergy development programmes. In the first biofuel development and implementation programme (GAVE), advanced biofuels were the only biofuels funded. In the same period (1998-2001), tax exemptions for conventional biofuels ceased. Advanced biofuels gained continued funding, but remained at an R&D level throughout the time studied. However, conventional biofuel entered the market. The boating niche evolved in tandem with small-scale tax exemptions in the late 1990s. From 2002, larger and longer term tax exemptions for biodiesel and PVO aided the development of a few hundred PVO/ biodiesel vehicles and a few related production plants. The emerging biodiesel and PVO market was visible in the first half of the 2000s (see Figure 19). In the latter half of the 2000s, a law to incrementally increase biofuel distribution was complemented by a one-year general tax exemption in 2006. This led to the explosive growth of the low-blend market and an ethanol FFV market of about 5000 vehicles. A biofuel pump subsidy contributed to the expansion of FFVs and related infrastructure. The expansion in low blends is visible in the sharp increase in biofuel use shown in Figure 19. The figure also indicates the end of the biofuel market expansion in 2007. Thereafter, the biofuel market shows large annual fluctuations, particularly for biodiesel and PVO. The PVO/biodiesel vehicle market is heavily reduced. In line with market developments, Table 44 indicates a biofuel policy which is more cautious with regard to conventional biofuel development. This is reflected in reduced biofuel targets at the national and EU levels, and in the set up of policies to stimulate particularly sustainable and advanced biofuel developments and implementation, such as the Biofuel Innovation programme, double counting and sustainability criteria.

9.2.2. SNM analysis

From the analytical perspective of SNM, the development of biofuel networks, expectations and learning can explain the development of biofuels (socio-technical configurations) described above. I outline these patterns below, with examples from key biofuel experiments.

Networks

Despite only weak and intermittent government financial protection, especially strong network leaders, such as the Province of Friesland for biodiesel and the Aberson entrepreneurs for PVO, attracted followers and drove biofuel development forward. Other actors, such as the municipality of Rotterdam, managed to attract the support of an international network (BEST) to facilitate the development of FFVs at the end of the 2000s. The network leaders, entrepreneurs or local authorities (municipalities, provinces), were generally supported by a relatively wide and heterogeneous group of actors, contributing to production, distribution and vehicle technology. The biofuel distribution obligation in the mid-2000s stimulated the emergence of a separate biofuel network – a low blend network led by the petrochemical industry. This complemented the pure and high blend biofuel trials with a swiftly expanding market for low blend biofuel use with fossil fuels. Collaboration among network actors increased slightly over time, the ethanol actors in particular benefited from collaboration with importers in Rotterdam, but this was generally limited to actors focused on the same biofuel type and market.

Advanced biofuel development had a quite homogeneous network of scientists with temporary support from industry and the government. While the scientists had a leading role and indicated increased collaboration over time, the industrial actors were only involved as long as the government provided sufficient financial incentives. This was evident in their withdrawal as soon as government subsidies ran short, for instance when the industrial partners left Nedalco's ethanol project in 1998 and Shell left the FT project in the late 2000s.

Expectations

The conventional biofuel network actors had great expectations of the creation of a biofuel road vehicle and boating market. These biofuel developments were expected to meet increased environmental demands (e.g. stricter norms for surface water and for inner city pollution) and to aid the economy of regional actors such as farmers. This pure or high blend biofuel promise shifted in the mid-2000s. First, from a focus on biodiesel and PVO vehicles to ethanol FFVs because biodiesel and PVO production suffered more from increasing feedstock prices and did not profit as much from international partners and new policy measures as ethanol did in the late 2000s. Second, there was a change from the domestic production of fuels based on agricultural crops to fuels based on waste feedstock and an increased acceptance of biofuel imports. This was also the time when petrochemical actors introduced a new, parallel technology option – a low blend biofuel market based on cheap imports. This development was triggered by the new policy which obliged petrochemical companies to distribute biofuels. Advanced biofuel actors saw the potential for creating an advanced biofuel market in the medium to long term due to the expectation that advanced biofuel would become less costly and deliver greater environmental benefits compared to conventional biofuel alternatives.

Advanced biofuel expectations followed a positive development trajectory as a result of fairly consistent government support. Conventional biofuel expectations, however, had ups and downs as a result of short-term and limited government tax exemptions. Conventional biofuel expectations grew over time in tandem with increased network support and more stable government incentives in the early 2000s. However, by the late 2000s reduced government support and higher feedstock prices had led to reduced conventional biofuel expectations, a withdrawal from high blend and pure biofuel vehicle initiatives and the stabilization of demand for low blend biofuel in fossil fuels. Towards the end of the period, there was also a slight reduction in advanced biofuel expectations.

Learning

Even in the early 1990s it was clear that the use of pure and high blend conventional biofuels was possible, with some minor technology adjustments. These required both technical knowledge for better operation (e.g. some engines or engine parts were more suitable than others) and social learning for greater user acceptance (e.g. reduced deep fried smells from biodiesel boats). The vast majority of these technical lessons were gained from abroad, including PVO and FFV engine technology.

Technical advances on advanced biofuels were made on an R&D level, which resulted in the realization of various pilot plants. As the promise of implementation in the medium to long term proved unrealistic, the implementation date was simply postponed but expectations remained positive. However, by the end of the 2000s severe bottlenecks became increasingly apparent leading to slightly reduced expectations and network activity. A general lesson is that government funds were a prerequisite for both conventional and advanced biofuel development and implementation. Government funds for advanced biofuels were more consistent than those for conventional biofuels, but the amount of funding was not that different considering the high costs of tax exemptions in comparison to R&D.

Taken together, the development and implementation of conventional biofuels in the Netherlands was a result of the generally positive development of biofuel networks, expectations and learning. The positive feedback from these niche building processes, however, was slowed by the small-scale and short-term government protection, which resulted in a particularly slow start to biofuel implementation in the early 1990s. Moreover, the type of protection measures meant that the main implementation of biofuels in the 2000s was in the form of low blend fuels, despite the fact that biofuel actors had previously focused on the development of high blend and pure biofuel propulsion. The advanced biofuel R&D niche was also advancing. Despite failures to keep the promises made, expectations remained relatively high supported by relatively strong actors and continuous government funding. The funds, however, were not sufficient to make the relatively immature technology fit for market implementation.

For both conventional and advanced biofuels, the degree and type of protection were more decisive than the niche processes for the realization of Dutch biofuel developments and the type of biofuel markets. However, from an SNM perspective, technology development which is not embedded in a wider socio-technical network, as in the case of low blend biofuels, is less durable.

9.2.3. Discourse analysis

To gain further insight into the development or non-development of biofuel protection in terms of policy instruments, the policy process was analysed using a discourse framework. The chosen discourse analytical concepts cover the development of biofuel discourses, their context, related coalitions and lobbying activities.

Biofuel discourses and context: wider discourses, events and policies

The first biofuel discourse concerned conventional biofuels only. EU policy and national actors who framed biofuel as a means to resolve the agricultural crisis aided early discourse development, resulting in the first biofuel tax exemptions. At a later stage, the idea of biofuels as a means to deal with environmental problems became more prominent. However, discourse development and related protection measures were hampered by the competing bioenergy discourse. The argument in the bioenergy discourse was that support for biofuels would mean a continuing protectionist agricultural policy and fewer environmental gains than bioenergy from waste and cellulose. The biofuel discourse answered this critique by paying more attention to the regional benefits. The fact that the bioenergy discourse had existed longer, was more institutionalized and served the interests of the petrochemical and vehicle industry by keeping the vehicle sector fossil fuel-based made it a tough competitor for the emergent biofuel discourse.

With the growing urgency for CO_2 reductions, reflected in the Kyoto Protocol and EU policy, CO_2 reduction in the energy sector alone was no longer seen as sufficient, but in need of complementary measures in the transport sector. Consequently, an advanced biofuel discourse emerged alongside the bioenergy discourse and shared the arguments of economic and environmental superiority over conventional biofuels. In addition to the environmental arguments, the advanced biofuel discourse benefitted from arguments associated with the innovation and economic growth discourse. By these means the advanced biofuel discourse met the interests of the government and petrochemical industry to a greater extent than the conventional biofuel discourse.

The return of support for conventional biofuel in the 2000s, reflected in larger tax exemptions and the biofuel distribution obligation, was a result of the EU biofuel policy. The inability to meet short term EU demands with advanced biofuel technology led to an adjustment of the advanced biofuel discourse to accept conventional biofuels as a bridging technology. This resulted in large scale government support for low blend imported biofuels, which could be more easily replaced than domestically produced biofuels, for use in biofuel specific vehicles.

The stagnation in biofuel policy protection after 2007 and the increase in funding of other fuel alternatives was the result of an international anti-biofuel discourse that gained ground due to increasing food prices and politically influential discourse coalition actors. The discourse labelled conventional biofuels 'agrifuels' that caused negative environmental and socio-economic effects such as starvation in developing countries. While advanced biofuels relied on other feedstock than food crops, growing support for the anti-biofuel discourse meant that their legitimacy also came under scrutiny.

Discourse coalitions, lobbying activities and target audience

The conventional biofuel discourse was mainly promoted by selected agricultural interest groups and single entrepreneurs. The main target of the coalition's activities was to gain more tax exemptions from the government. Lobbying activities took place in various media and in parliamentary debates at the national and EU levels. One strategy used was adjusting to the changing general discourse context, such as the discourse adjustment from biofuels as beneficial primarily for farmers' livelihoods to regional development in general in order to fend off growing criticism of biofuels as only serving the interests of farmers. Another example was the reference to the Netherlands as lagging behind other EU member states in biofuel implementation in order to increase the urgency and financial support for biofuel implementation. However, some contextual changes such as the emergence of an anti-biofuel discourse could not be fended off as easily and resulted in a regression of the conventional biofuel discourse and reduced policy protection. The counter strategies applied by conventional biofuel actors were to assure the production and use of the best possible biofuels by applying sustainability criteria or by associating with the advanced biofuel discourse by promoting waste as a feedstock.

The competing bioenergy and advanced biofuel coalition was promoted by coalition actors with large political influence, such as scientists and to some extent also industry (Shell, Nedalco) and government agencies (Senter Novem). Both the early bioenergy and the advanced biofuel coalitions lobbied against conventional biofuels and for increased advanced biofuel R&D and implementation support. Lobbying activities were mainly channelled through the scientific and popular media. A particularly successful strategy was the introduction of the first- and second- generation fuel terminology, which stressed the superiority of advanced biofuels over conventional biofuels and led to a polarization of the biofuel debate in the late 1990s. Another strategy was the acceptance of first-generation biofuels as a bridging technology, to maintain discourse support once the coalition actors realized that advanced biofuels were not able to meet the short-term implementation targets set out in the EU biofuel policy.

9.2.4. The Netherlands: conclusions

Following the SNM analysis, limited financial incentives (protection) by the government were decisive in the pace and type of biofuel development and implementation. The discourse analysis highlights that Dutch government protection of biofuels (R&D funds, tax exemptions and regulations) would not have come about at all if it had not been for the persistent and strategic lobbying activities of various biofuel coalition actors, and a series of events such as the agricultural crisis in the 1990s, increased CO_2 reduction targets and political pressure from the EU.

The discourse analysis indicates two main reasons for the limitation of conventional biofuel policy protection to small scale and temporary tax exemptions and later to a biofuel distribution obligation, resulting in low blend biofuel implementation by the petrochemical industry. The first reason is that many competing discourses (bioenergy, advanced biofuel and anti-biofuel discourses) used a variety of strategies to prevent the development of the conventional biofuel discourse, as outlined above. The second reason relates to the general context of values and interests influencing the biofuel policy process. The policy process reflects actors with overtly neoliberal values, objecting to large scale subsidies such as tax exemptions and other market regulatory measures. This is evidenced by the fact that funds were restricted not only in the case of conventional biofuels, but also for advanced biofuels that enjoyed high discourse support. Other evidence is that the biofuel distribution obligation was not so much driven by national actors as forced by the EU.

Moreover, a strong economic and political interest that has influenced the direction of biofuel development is the Dutch petrochemical industry. Against expectations that it would hamper all biofuel development, it supported advanced biofuels in the biofuel debate, because many advanced biofuel processes are based on petrochemical processes (e.g.

FT-diesel, HTU) and thus meet the interests of the industry to a greater extent than conventional biofuels.

Advanced biofuels were generally preferred in Dutch politics and were granted more consistent support than conventional biofuels, despite the immature state of the process technology. The influential position of the petrochemical industry and the many discourses promoting advanced biofuels contributed to the more consistent support for advanced biofuels compared to conventional biofuels. While funding for advanced biofuels was more consistent than for conventional biofuels, the subsidies were restricted to R&D, which is less financially demanding compared to the early tax exemptions given to conventional biofuels.

9.3. BIOFUEL DEVELOPMENT IN SWEDEN, 1970-2010

Sweden has had a leading position in biofuel implementation among EU member states. As in the case of the Netherlands, this may partly be explained by some more or less obvious connections to domestic industry and natural resources. For instance, Sweden does not have any fossil fuel resources or industry. This has made the fuel market more open to alternatives. The focus on biofuels, especially ethanol (see Figure 20 and Figure 21), is likely to be related to the vast biomass resources in terms of forests and the bulk production of starch crops. Moreover, the forest industry represents strong interests since it is one of the biggest 'base industries' in Sweden. While these observations might serve as a backdrop for analysing the reasons for biofuel development, more elaborate insight has been gained through the SNM and discourse analyses. I start this section by summarizing the development of Swedish biofuel (socio-technical configurations) and related policy. The SNM and discourse analyses are then outlined and conclusions drawn.

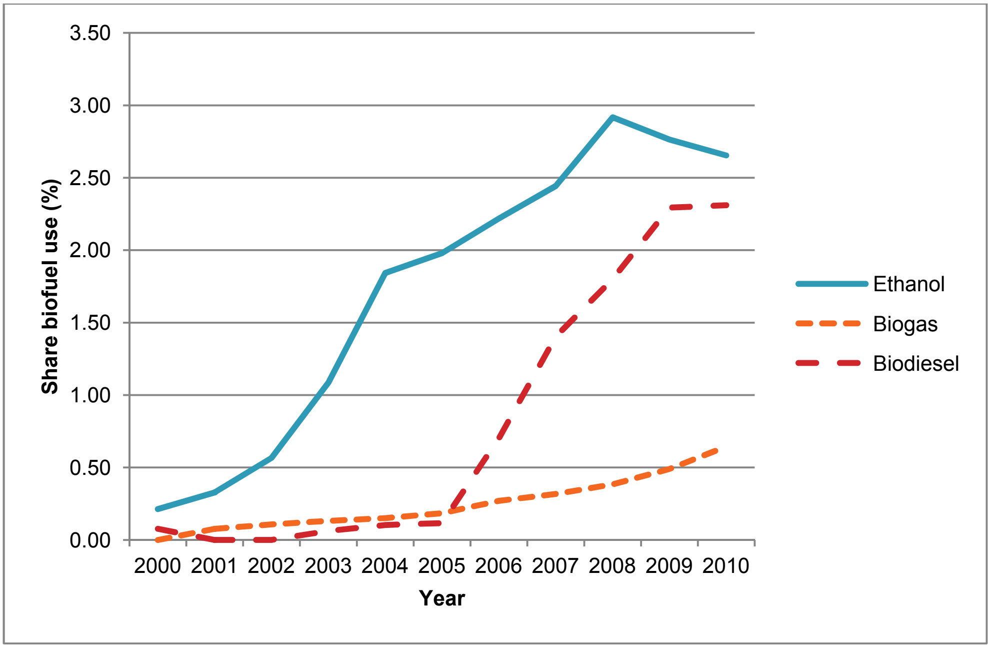

Figure 20: Share of ethanol, biodiesel and biogas in use of total road transport fuels, 2000-2010.
Source: Statistics Sweden, the Swedish Energy Agency and the Swedish Gas Association.[95]

[95] The share of biofuel use has been calculated based on the energy content of the biofuels and total fuels (alternative and fossil) used in the road transport sector.

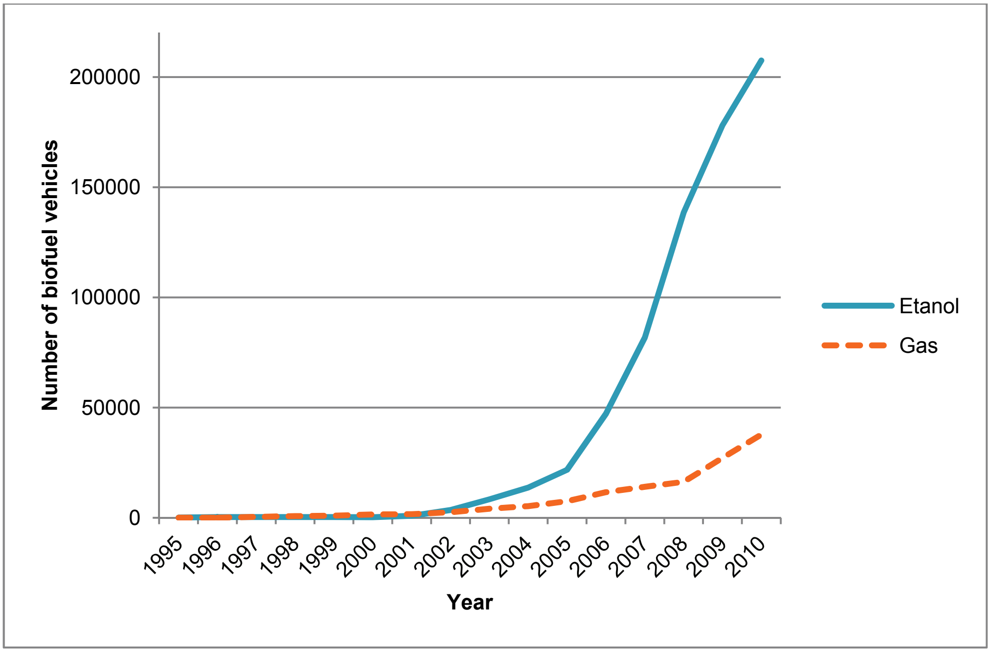

Figure 21: Number of light and heavy ethanol and gas (biogas and natural gas) vehicles
Source: 1995-1999 Energigas Sverige, Pädam (Pädam, 2009), 2000-2010 www.miljofordon.se , 2009-2010 (Pädam et al., 2010; Larsson & Karlsson, 2011) [96]

Years	Biofuel related policy events
1975	1975-1984: Energy Research Programme increased methanol subsidies. 1975-1981: Swedish Methanol Development Company (SMAB).
1980	Tax exemption methanol (50% reduction per volume).
1981	Tax exemption ethanol (50% reduction per volume). 1981-1985: SMAB becomes State's Propellant Technology Company (SDAB).
1983	Foundation for Swedish Ethanol Development (SSEU) founded.
1984	Methanol subsidies ended.
1990	1990-1995: CO_2 tax exemption for all biofuels.
1991	1991-1995: Energy tax exemption (total tax exemption) for ethanol/methanol.
1992	1992-1997: Biofuel Programme to support mainly conventional ethanol and biogas.
1993	1993-1997: Advanced ethanol R&D programme. 1993-1995: Energy tax exemption (total tax exemption) for biodiesel.
1995	EU membership and adjustment of biofuel tax exemptions to temporary pilot exemptions.
1996	From 1996: R&D funds for synthetic biofuels successively increased through various programmes, e.g. Biofuel Programme.
1997	1997-2002: restricted tax exemptions ethanol and biodiesel. 1997-2002: Local Investment Programme (LIP) supports biogas.

[96] The data include all vehicles modified to run on pure or a large share of biofuels, such as ethanol flexi-fuel vehicles and bi-fuel gas vehicles. The data 1995-2003 do not include heavy vehicles, buses and trucks, while the data 2004-2010 do. It has however been a very small share of the market in recent years. In 2010 the biofuel heavy vehicle market was just over 600 for ethanol and 5200 for gas.

	1997-2000: 10% ethanol E10 used in some conventional gasoline.
1998	1998-2004: 2nd Ethanol R&D programme. 1998: various municipal financial incentives for biofuel vehicles (mainly ethanol and biogas but initially also biodiesel vehicles).
1999	SSEU changes name to Bio Alcohol Fuel Foundation (BAFF).
2000	2000-2006: subsidies for biofuel (ethanol and biogas) lease vehicles. EU restricts ethanol blend to 5% (E5) in gasoline.
2003	EU Biofuel Directive published, setting indicative biofuel targets for 2005 and 2010. EU Fuel Tax Directive permits general biofuel tax exemptions. 2003-2008: Climate Investment Programme (KLIMP) supports biogas.
2004	2004-2008: General biofuel tax exemptions (exemption CO_2 and energy tax) reintroduced Government set a 3% biofuel implementation target for 2005 instead of the 2% indicative target of the EU.
2005	Pump law benefitting ethanol E85 distribution. Policy goal that Sweden should be independent of oil by 2020.
2006	Standard of 2% biodiesel (B2) in conventional diesel is increased to 5% biodiesel (B5). 2006-2008 Subsidy scheme for gas pumps.
2007	EU proposes obligatory biofuel implementation of 10% by 2020. 2007-2010: 3rd Ethanol R&D programme.
2008	EU plan for obligatory implementation target withdrawn. 2008-2013: General tax exemption for biofuels prolonged.
2009	EU Renewable Energy Directive (RED) promotes implementation of second-generation biofuels and alternative fuels, provided sustainable criteria are met.
2012	Government implements sustainable criteria according to EU RED.

Table 45: Main Swedish biofuel policy events, 1970-2012

9.3.1. Swedish biofuel policy and technology development

As is indicated in Table 45, Swedish biofuel development began in the 1970s with advanced bio methanol R&D and fossil methanol vehicle trials. Methanol development was coordinated by the Swedish Methanol Development Company (SMAB), later known as the State's Propellant Technology Company (SDAB), and largely supported by government funds. It was a private and public sector collaboration that, among other things, carried out an experiment with 1000 low blend methanol vehicles in the early 1980s. However, the incrementally increased methanol subsidies and trials were ended in the mid-1980s, while emerging small-scale support for conventional and advanced ethanol continued. The early ethanol tax exemptions supported ethanol imports, domestic sulphate ethanol production and a temporary wheat ethanol plant feeding the development of ethanol buses to a small market niche in the early 1990s. This was followed by the development of a Biofuel Programme, which together with expanding ethanol tax exemptions contributed to the establishment of an FFV market and a small low blend market in the late 1990s as well as large-scale wheat ethanol production in the 2000s. In 1993, tax exemptions were also adjusted to facilitate growing biodiesel experiments. As a result of Swedish EU membership in 1995, the general tax exemptions for ethanol and biodiesel had to be adjusted to fit EU tax exemptions restricted to biofuel pilot projects only. The EU made an exception for biogas, which kept the general tax exemptions that had been granted in the early 1990s, resulting in an expansion of local biogas production and related vehicle markets. However, the EU imposed additional restrictions on ethanol in the form of a limitation of ethanol blends to 5%.

Another restrictive factor was the reduced tax exemptions for ethanol and biodiesel between 1997 and 2004. This had a particularly negative effect on biodiesel, demonstrated in the dip in 2001-2002 in Figure 20. Unlike ethanol, biodiesel faced harsher restrictions on tax exemptions and did not enjoy as many national and municipal incentives as biofuel vehicles (e.g. tax reductions on biofuel vehicles, free parking and exemptions on congestion fees) at the turn of the century. In the mid-2000s, government policy incentives increased with the return of general tax exemptions and increased subsidies for light vehicles and pure/high blend biofuel distribution locations. This led to an explosion in low blend use, which is particularly visible in the increase in biodiesel as shown in Figure 20. In the case of ethanol, increased low blend use was a complement to the growing FFV market (see Figure 21), which had resulted in increased ethanol consumption in the early 2000s (see Figure 20). Figure 20 indicates a slight reduction in ethanol use and a stabilization of biodiesel use in the last two years. That Figure 21 indicates continued growth of ethanol FFV sales despite reduced ethanol consumption seems contradictory. However, increases in FFV sales do not necessarily mean increased ethanol consumption since these flexible vehicles can run equally well on gasoline alone. In fact, data show that reduced ethanol consumption at the end of this period relates to reduced ethanol use in FFVs. The dip in biofuel expansion in the latter half of the 2000s (see Figure 20) is also reflected at the policy level, particularly at the EU level, where biofuel support measures were reduced and strict conditions for support (e.g. sustainability criteria) were introduced. However, the use of gas (natural gas and biogas) did not show any reduction in expansion (see Figure 20 and Figure 21) and the general tax exemptions for gas and various local and national support programmes (e.g. LIP, KLIMP, subsidy scheme for gas pumps) remained at the same level.

In addition to the conventional biofuel market niches visible in the statistics, various advanced biofuel R&D niches emerged as a result of extensive biofuel R&D programmes from the 1970s onwards. As is indicated in Table 45, funds from the late 1980s onwards focused on cellulose ethanol, which resulted in a pilot plant in 2004. During the 2000s, R&D subsidies for advanced alternative synthetic fuels re-emerged after the ending of advanced methanol subsidies in the 1980s. Unlike the synthetic fuel focus on methanol in the 1980s, the focus in the 2000s was on advanced biodiesels, which resulted in a DME pilot plant in 2006 and related vehicle trials.

9.3.2. SNM analysis

The Swedish SNM analysis used three niche processes – networks, expectations and learning – to explain the socio-technical configurations of biofuel development. These niche processes are described below with reference to key biofuel experiments.

Networks

In line with the SNM framework, successful biofuel niche developments of early methanol, ethanol and biogas were led by strong biofuel networks with the broad involvement of actors from production to distribution and use. Another trait of the successful biofuel networks was that public authorities were in leading positions. The methanol network was led by the government and initially also by the vehicle industry, Volvo. Despite successful development, however, the government decided to terminate the project in the mid-1980s, which resulted in network collapse. The ethanol network was led by two clusters that cooperated in creating an ethanol market. The cluster focusing on conventional ethanol was led by farmer organizations while the cluster focused on advanced ethanol development (also known as SSEU and later BAFF) was led by the chemical industry, SEKAB, local municipalities and scientists. In the biogas case, municipalities took the lead in what was only a relatively homogeneous network of various municipal actors that benefitted greatly from collaboration with the natural gas industry. In the case of DME development, municipalities were also in a leading position at an initial stage, but thereafter industry played a greater role. Like the other successful biofuels mentioned above, a strong and broad network contributed to the relatively fast development of this technically advanced biofuel.

Less successful biofuel developments, such as early bio oil and biodiesel, can be explained by their relatively weak and homogeneous networks, which consisted mainly of farmers. Later biodiesel development was mainly supported by fuel distributors. Even when the biodiesel market share increased in the 2000s, the network remained rather narrow and there was no involvement of public authorities as in the other biofuel networks. This is partly explained by the low blend focus, which demanded less change in technology and infrastructure, and thus less variety of actors for the implementation of the technology.

Expectations

Successful biofuel developments (early methanol, ethanol and biogas) were supported by network actors' positive expectations. Aided by the 1970s oil crisis, initial biofuel expectations were focused on methanol – an advanced biofuel technology. Methanol was expected to have the best market potential for large-scale oil substitution due to its cheap raw material (wood), low cost and relatively good fit with vehicle technology. Natural gas methanol was expected to aid market expansion until bio-methanol production was sufficiently mature. With the stabilization of oil prices in the mid-1980s, the promise of a large scale commercial market for advanced methanol technology lost ground. In the early 1980s, a parallel promise of conventional ethanol as a potential oil substitute and lucrative business for farmers emerged. At a later stage, expectations shifted to the increasingly wide regional economic and environmental benefits of ethanol. Moreover, conventional ethanol was to serve as a bridging technology for a more cost- and environmentally efficient cellulose ethanol, which was expected to become competitive with fossil fuels in the future. Environmental benefits were also central to positive biogas expectations – it was labelled 'the most environmental fuel' in the late 1990s. Expectations of environmental gains were coupled with expectations of regional economic development and a profitable solution to the management of local waste, which was used as feedstock for biogas production. The initial technology expectation that biogas development could benefit from using natural gas engines was complemented by additional expectations that biogas market expansion could benefit from the natural gas distribution infrastructure. In the late 1990s, particularly positive expectations of advanced synthetic biofuels returned after failures with methanol in the 1980s. However, methanol expectations had to give way to stronger advanced synfuel expectations, particularly of DME.

Biofuels with low expectations attached to them displayed less successful development. One example is biodiesel, which was expected to have less potential for market expansion compared to ethanol due to the limited ability to cultivate feedstock. This contributed to the lack of committed biodiesel actors. There was also a connection between limited government support and low expectations. Biodiesel, with its relatively lower expectations compared to ethanol and biogas, gained relatively fewer financial incentives from the government and municipalities, particularly in the period from the 1980s to the early 2000s. Another example is the reduction of cellulose ethanol expectations and government financing of cellulose ethanol towards the late 2000s. The latter was a surprising turn given that cellulose ethanol had enjoyed continuous funding despite the fact that positive technology expectations had not materialized. Instead, dates for advanced biofuel market introduction have been postponed.

Learning

The sharing of positive lessons contributed to successful biofuel developments since they often reinforced positive expectations, and expanded and strengthened networks. Clear examples of this include the spread of the FFV and biogas market niches based on positive experiences feeding positive expectations. The successful development of ethanol and biogas was in particular facilitated by learning processes that linked a variety of lessons, technical, social, geographical, institutional and financial, which led to increased societal embedding. Examples include the reduction of ethanol exhaust smells and biogas production smells by learning from users, the adaptation of ethanol vehicle fuel to fit Swedish climate conditions and the upgrading of biogas to natural gas standard to benefit from existing gas infrastructure and engine technology

Less successful biofuel development was connected with absent and negative learning processes. Lack of learning hampered biogas development in Stockholm due to the implementation of a distribution technology that did not fit local conditions. Negative lessons were linked to the limited domestic feedstock (rapeseed) for PVO and biodiesel production, the limited environmental benefits of biodiesel compared to other biofuels and the difficulties in achieving advanced methanol production. These lessons hampered positive expectations and actors' motivation to engage in development. However, there were exceptions. Like methanol, cellulose ethanol did not manage to keep the promises made, but activities continued and expectations remained positive. With increased awareness of the technology barriers in the late 2000s, however, expectations and activities were reduced.

A central lesson is that financial protection is a prerequisite for biofuel development. Examples are the abrupt ending of the methanol experiments as a result of funding cuts, the shift in network actors' development focus from ethanol buses to FFVs in the early 1990s due to budget cuts in public transport companies, and the reduced use of biodiesel blends due to reduced tax exemptions in the early 2000s.

Consistent with the SNM literature, the positive development of early methanol, ethanol, biogas and later low blend biodiesel went hand in hand with financial incentives from national and local authorities and niche dynamics, which mutually reinforced each other. Looking closely at the different niche processes, the involvement of strong network actors, such as public authorities or industry, and positive expectations seem more crucial for development than a wide, heterogeneous network and positive lessons. However, of the three biofuel market niches that emerged at the end of the period, the high blend and pure biofuel market niches involving ethanol and biodiesel could be considered the most stable, since they involved larger and more heterogeneous networks and large scale socio-technical change. This was not the case for low blend biofuels, such as biodiesel, which society could more easily abandon.

9.3.3. Discourse analysis

To gain further insight into the development or non-development of space in terms of policy instruments, the policy process was analysed using a discourse framework. The focus of the analysis was the development of the biofuel discourses, their contexts, and related coalitions and lobbying activities.

Biofuel discourses and context

The initially large amount of government funding for methanol R&D was partly due to the 1970s oil crisis, which opened up the political arena for alternative fuel actors. Despite the existence of ongoing sulphate ethanol production and a large Swedish alcohol industry, a biofuel discourse developed that presented the immature methanol fuel as the best substitute for oil due to its relatively low production costs, its use of domestic feedstock and its suitability for current engine technology. Increased urgency for oil substitution in the late 1970s led the advanced methanol discourse to include natural gas methanol as a bridging technology. In the 1980s, the stabilization of low fossil fuel prices put an end to the methanol discourse and related support measures. However, emerging ethanol funds remained due to successful adjustments of the ethanol discourse to the growing environmental discourse. The general arguments in the ethanol discourse were that ethanol was the alternative fuel with the best (local and national) economic and environmental benefits. More specifically, conventional ethanol would generate optimal economic and environmental benefits in the short term and advanced biofuel in the long term. Another event that benefitted early ethanol development was a policy deadlock in 1990 which led to a three-party agreement involving large subsidies for ethanol and later biogas in the form of a biofuel development programme.

Initial support for biogas was stimulated by the natural gas discourse, which presented biogas as a bridging technology. However, when biogas promoters formulated an individual biogas discourse arguing a better environmental and regional development effect compared to natural gas, biogas was granted exceptional biofuel policy support. In addition to funds from the biofuel programme, biogas was the only biofuel to enjoy a general tax exemption, which began in the 1990s, and geographical market protection – a government restriction on further natural gas net expansion to avoid competition with biogas. The increased priority given to sustainability in Swedish politics and the ranking of biogas as the most environmental fuel alternative in the late 1990s contributed to biogas discourse expansion and the additional support programmes (LIP/KLIMP). However, there were also limiting factors, such as statements made by ethanol and synthetic fuel coalitions that biogas was a mere niche fuel due to the limited availability of feedstock. A similar criticism was also directed at biodiesel.

The sustainability focus of the late 1990s led to increased criticism of the emissions reduction potential of conventional ethanol and biodiesel from proponents of synthetic gas, among others. This contributed to restricted tax exemptions for ethanol and biodiesel between 1997 and 2004 and cut municipal support measures for biodiesel. To counter this negative development, ethanol and biodiesel actors joined forces in a biofuel discourse. The biofuel discourse was evident in arguments that conventional biofuels were the best environmental option in the short term and a necessary bridging technology to advanced biofuels. The biofuel discourse was strengthened by the development of an EU biofuel discourse and biofuel implementation policy. The biofuel discourse was particularly profitable for biodiesel, which went from a relatively unknown fuel alternative to a legitimate, low blend biofuel.

The synthetic fuel discourse criticising conventional biofuels could be seen as a mild forerunner of the international anti-biofuel discourse, which presented biofuels as leading to environmental degradation and other negative socio-economic effects – a discourse aided by the increasing prices of crops. The peak of the anti-biofuel discourse in 2007 and 2008 had an impact on conventional biofuel discourses, which were steered towards increased promotion of more sustainable biofuel production chains and certification. Policy development followed a similar pattern, with increased attention to other potentially sustainable fuel alternatives alongside biofuels, particularly at the EU level. However, national biofuel policy protection remained largely intact, except for some adjustments to fit the EU legal framework.

Biofuel discourse coalitions and lobbying activities

The initial domination of the methanol discourse was aided greatly by a methanol coalition led by the vehicle industry and the government. The particular strength of the methanol coalition was indicated by the fact that it could gear all alternative fuel funding to methanol, an advanced and yet immature fuel technology, even though there were other mature options such as ethanol with very similar properties. The ethanol coalition involved an industrial actor, the chemical industry (Sekab), but also farmers' organizations (to some extent represented by the Centre party) and municipalities. The biogas coalition was run by municipal actors alone, with support from the natural gas industry in the early 1990s and the late 2000s. Industrial and municipal actors were also influential in the emergent DME coalition.

All the biofuel coalitions used various media sources to spread information. Ethanol and biogas actors complemented this with wider public campaigns. The methanol coalition directed their lobbying activities to a wider public in order to legitimize further support and market expansion, since the government was already a central actor in the project. Other biofuel coalitions had the government generally and occasionally also the EU as the target audience for their activities aimed at securing subsidies.

The strategies used were different depending on the context. For example, a strategy by the ethanol coalition in the early 1980s, when the methanol discourse dominated, was to stress the similarities between ethanol and methanol by referring to ethanol as an 'alcohol'. A common strategy applied by all biofuel actors was the bridging technology strategy, in which both short-term and long-term solutions are presented in order to secure continuous discourse support. Examples of this include: first, natural gas methanol as a bridge to advanced bio methanol; second, natural gas as a bridge for biogas; and, third, conventional biofuels as a bridge to advanced options – as in the ethanol discourse and general biofuel discourse. For the biofuel discourse, the bridging argument was also a means to fend off criticism of conventional biofuels such as ethanol and biodiesel as outdated and not delivering sufficient environmental benefits.

While relations between coalitions were generally friendly and collaborative, some coalition actors used criticism of other biofuels as a strategy for advancing their own discourse. A mild version was applied by several coalitions when arguing that their biofuel option had better environmental properties than other biofuels. As exemplified above, harsher criticism was presented of conventional ethanol and biodiesel by the early synthetic fuel coalition, led by public authorities; and by the international anti-biofuel coalition, led by scientists and various political actors.

9.3.4. Sweden: conclusions

The SNM analysis highlights that protection by means of policy incentives facilitates niche internal processes and the development of socio-technical configurations. The discourse analysis indicates that the type and degree of government incentives are dependent on a variety of factors regarding the type of actors, their beliefs and interests, and the way they interact with each other and in relation to their changing institutional context.

The discourse analysis strengthens the claims in the introduction that a number of national circumstances related to natural resources and political culture facilitated biofuel development, especially of methanol and ethanol. First, the lack of fossil fuel resources and the existence of vast forest resources and a forest industry (mainly paper and pulp) contributed to the interest in advanced alcohols as a substitute for fossil fuels. The existence of a starch-based agricultural industry contributed to a focus on ethanol, not least because the agricultural and forest industry was highly visible in promoting ethanol fuel. Large scale biodiesel production from oil crops does not fit that well with Swedish agricultural conditions, which also explains the limited interest and policy support at an early stage. Second, the Swedish political culture also contributed to the direction of development. An example is the particularly strong environmental values in Sweden, reflected in the high CO_2 reduction goals set for the transport sector and the wish to hold the position of an international frontrunner in environmental policy. Another example is the social democratic political tradition, which has allowed relatively strong market intervention by the government, visible in the strong government participation in the biofuel projects as well as the large subsidies given. However, this does not fully explain Sweden's biofuel development pattern.

The discourse analysis shows that a strong coalition of politically influential actors, such as in the early methanol case, is more successful in gaining legitimacy and government support than a weak coalition, as in the case of biodiesel. The commitment of strong and politically influential actors in the methanol coalition also explains why methanol was funded and introduced before ethanol despite much more experience of using ethanol fuel. The success of the strategies applied by these coalition actors is also significant, such as the framing of ethanol and biogas as an answer to current problems related to the environment and regional economic development. In addition, the discourse analysis shows that policy protection may not always be actively created by politically influential actors. It may emerge out of various political circumstances, such as the biofuel programme emanating from the 1991 Three-party Agreement.

9.4. A COMPARISON OF DUTCH AND SWEDISH BIOFUEL DEVELOPMENT

This section compares biofuel development in Sweden and the Netherlands in order to answer the main research question. The differences between the biofuel development patterns are summarized and then explained based on insights from the SNM and discourse analyses.

9.4.1. Differences in biofuel development

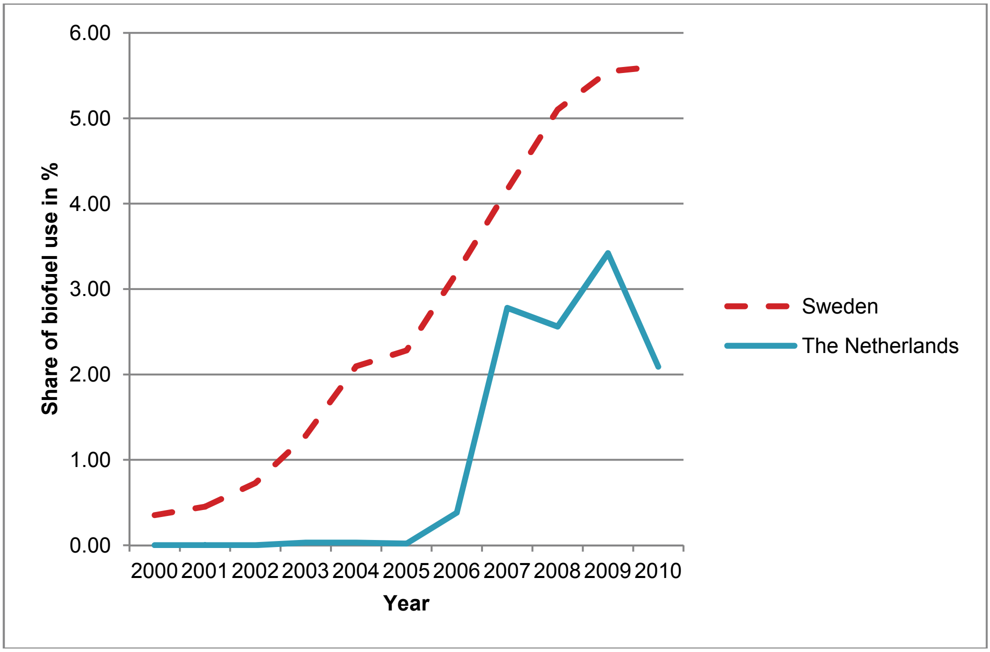

Figure 22: Share of biofuel use in total road transport fuels, 2000-2010.
Source: Statistics Sweden, the Swedish Energy Agency, the Swedish Gas Association and Statistics Netherlands

There is a large difference in the size and type of biofuel markets in Sweden and the Netherlands. Figure 22 shows that the Swedish biofuel market share is more than double that of the Netherlands. In addition, Sweden has a larger biofuel vehicle fleet and related infrastructure compared to the Netherlands. While there are no exact data available on biofuel vehicle use in the Netherlands, there is an indication that more than 5 000 ethanol FFVs were running in the Netherlands in 2010. In Sweden, the corresponding number was just over 207 000 ethanol vehicles (see Figure 21). In addition, Figure 20 and Figure 21 indicate the great number of biogas propelled vehicles running in Sweden. The exact number is hard to estimate due to the ability to fuel gas vehicles with both natural gas and biogas.

One explanation for the large market implementation in Sweden is the fact that Sweden has been experimenting with biofuels for a longer period, since the early 1970s instead of the early 1990s as in the Netherlands. Longer development time is likely to correspond with greater opportunity for *learning*. The Swedish case shows examples of various types of lessons and the linkages between these lessons, which facilitate a greater embedding of the technology in society. However, both cases show development patterns of technology optimization of already available technology systems (e.g. (bio)fuels, distribution infrastructure and engine technology) instead of radical transformation towards a more sustainable transport sector.

While both countries indicate the involvement of public authorities in biofuel *networks*, the Swedish case shows a greater degree of public authority involvement from both local and national governance levels. There is also an indication of larger and more heterogeneous networks and more collaboration and alignment among Swedish biofuel actors compared to the Dutch biofuel actors. This is partly a result of the greater degree and type of biofuel niche development. The increased focus on pure and high blend vehicles in Sweden requires the involvement of many different types of actors.

While positive *expectations* have been visible in both cases, they have been more positive and widespread in Sweden. Expectations have been fed by positive developments (learning), positive network development and government protection, which has been greater and more consistent in Sweden than in the Netherlands. In fact, both cases show that government protection has been crucial for the establishment of a positive feedback loop of network creation, expectations and learning. Without government protection, biofuel development and implementation would not have been possible.

9.4.2. Differences in policy development

The degree and types of biofuel implementation are also explained by the different types of government protection measures applied. While both countries gave continuing protection to advanced biofuels, Sweden gave much larger and more consistent biofuel protection to conventional biofuel than the Netherlands. This resulted in earlier and larger scale conventional biofuel market implementation in Sweden. For conventional biofuel implementation, the Dutch government prioritized regulation while the Swedish government prioritized subsidies. In addition to short term and small scale tax exemptions, the Dutch government implemented a regulation that obliged biofuel implementation by biofuel distribution companies, which resulted in a biofuel market greatly dominated by low blend biofuels in fossil fuel. The Swedish government prioritized tax exemptions for biofuels and biofuel vehicles, subsidies for biofuel vehicles and distribution infrastructure and implemented a regulation involving geographic protection of the biogas market from natural gas competition. This resulted in the establishment of a high blend/pure biofuel market and a low blend market.

The strong preference for and more consistent protection of advanced biofuels in the Netherlands and the resistance to implementation of less promising conventional biofuel solutions indicate a supply-driven technology-fix perspective, that is, an increasingly innovation-driven search for an optimal technology solution to resolve a problem in the transport sector. The Swedish approach, focused on biofuel market creation by means of conventional technology in parallel with more advanced technology development, also serves a technology solution but indicates a more demand-driven approach. This approach is reflected in a greater public urgency that motivates the implementation of biofuels to reduce problems in the transport sector.

The greater discourse support for the advance of high blend and pure biofuel vehicle markets in Sweden compared to the Netherlands also contributed to greater institutionalization of the Swedish biofuel niche market. Low blends, mainly supported in Dutch politics, require hardly any adaptation of the conventional fossil fuel infrastructure and engine technology compared to high blend use, and thus less adaptation of various actors' ideas and behaviour in order to implement that technology.

In the creation of government protection measures, the Swedish example shows a more successful and smoother discourse development pattern. Collaboration and peaceful coexistence have been increasingly visible among Swedish biofuel coalition actors, which promoted various biofuel bridging scenarios and constructed a common biofuel discourse. The Dutch case has shown a much higher degree of competition and antagonism towards and between biofuel coalitions. In particular, the forces resisting conventional biofuel discourse development, such as the bioenergy, advanced biofuel and the anti-biofuel discourses, were stronger and had more successful strategies than in Sweden. One example of the Dutch forces against conventional biofuel is the introduction of first- and second-generation biofuel terminology by the advanced biofuel coalition in order to stress its superiority to conventional biofuels. This is yet another explanation for the generally weak government protection and implementation of conventional biofuels in the Netherlands. However, brief periods of reduced antagonism contributed to positive biofuel development there too. Such a period occurred in the early 2000s after the publication of the EU Biofuel Directive.

That the Swedish actors were more collaborative and positive about biofuel development than the Dutch can be traced to differences in industrial structures and access to natural resources. Sweden had no ties with the petrochemical industry, but the forest industry was one of the most influential industries and biomass (forest and starch) suitable for biofuel production was abundant. The Netherlands was highly dependent on the petrochemical industry and its contribution to the economy and had hardly any access to biomass suitable for biofuel production. These contextual factors were reflected in the values and interests of actors as well as in the biofuel coalition strategies and related discourse developments. Regarding biofuel coalition strategies, the potential environmental gains of biofuels were referred to by the biofuel coalitions in both countries. However, the particular Swedish context implied that additional coalition arguments for biofuel development relating to increased independence from oil and economic gains from domestic biofuel production are likely to have aided Swedish discourse development to a greater extent than in the Netherlands.

The differences in national context, policy processes and biofuel coalitions meant that policy events played out differently in the two cases. In the Dutch case, the oil crisis of the 1970s triggered an increased market share for LPG, while in the Swedish case it triggered biofuel development. The political pressure from the EU forced the Dutch government to approve the EU Biofuel Directive and conventional biofuel implementation. In the Swedish case, EU policy was generally seen as a barrier to biofuel development. Examples are the adjustments to EU regulations which restricted general tax exemptions to time-limited pilots and ended experiments with 10% ethanol blends. However, Sweden embraced the EU Biofuel directive and this stimulated additional biofuel market development.

9.5. DISCUSSION

Based on the biofuel analysis I conclude that an SNM analysis alone cannot explain the difference in Swedish and Dutch biofuel niche development. Niche internal processes – expectations, network formation and learning processes – do not provide sufficient explanation for the way in which biofuels are developed since they do not explain why certain biofuel projects are protected while others are not. Adding a discourse analysis of the policy process to the SNM analysis contributes to the SNM framework by providing a more elaborate explanation of policy-related protection measures and the dynamics of niche development.

From this conclusion, several new questions emerge around these two analytical perspectives, such as the way in which these perspectives can be integrated in order to contribute to transition theory in the best way. While many of these issues will be left for future research, this section looks more closely into the integration of the SNM and discourse frameworks. In particular, concepts from different frameworks that are closely related or overlap in function are discussed, since they pose a problem for the development of an integrated framework. Based on this discussion, theoretical and policy conclusions are drawn and potential future research topics identified.

The two main overlapping concepts in the SNM and discourse frameworks are, first, the niche network concept with the discourse coalition concept and, second, the niche expectation concept with the discourse concept. According to SNM theory, network actors engage in technology development and implementation. According to the discourse theory, coalition actors engage in various strategies in order to influence the policy debate in the direction of their beliefs and interests. If the coalition actors are successful, their ideas are gathered in a discourse that gains public legitimacy and policy support. Hence, while network actors act in an innovation arena, coalition actors act in the policy arena.

The analysis of biofuel development in this thesis indicates that network actors engage primarily in biofuel experimentation activities, but that many of them engage in discourse coalition activities as well. A great variety of actors operate in both a niche network and a corresponding discourse coalition: for example, entrepreneurs such as the Abersons in the Dutch PVO case, industry like the chemical company SEKAB (partly active within SSEU) in the Swedish ethanol case, scientists such as those in the Dutch advanced biofuel case, and local authorities such as the Municipality of Rotterdam in the Dutch ethanol FFV case and the many municipalities involved in the Swedish biogas case. A common trait among the niche network actors that operate in coalitions at the policy level is that they usually have a leading or an otherwise central position in the niche network and in the coalition. There were also coalition actors that had no connection to network activities. These coalition actors were generally politicians or political organizations. For example the Dutch political party members lobbying for biodiesel and PVO, the Swedish Centre Party lobbying for ethanol, the Swedish authorities in the synthetic fuel case in the late 1990s, and the NGOs involved in the international anti-biofuel discourse. That an increasing number of network actors take part in coalition activities is shown by means of the arrow from the niche network to the discourse coalition in Figure 23.

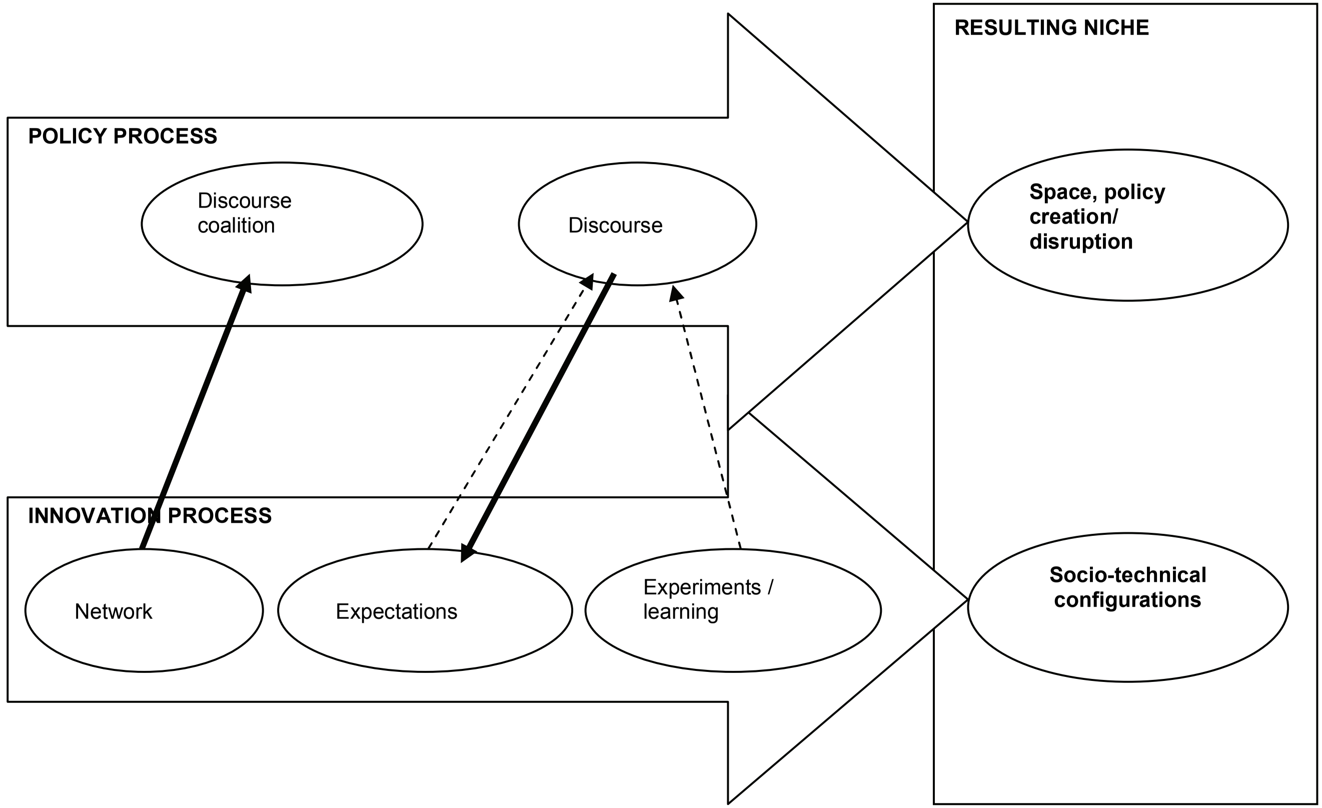

Figure 23: Main links between the SNM and discourse concepts in the analytical scheme

There is also a certain overlap between the niche expectation concept and the discourse concept. According to SNM scholars, expectations may be voiced by individual actors or an existing niche network in order to give direction to technology development, and attract network actors and resources for technology development. The activity of attracting resources by voicing expectations is what some SNM scholars present as a means to generate protection, which can involve policy incentives. This policy protection-generating function of expectations in particular closely resembles the function that coalition actors aim to generate when trying to gain legitimacy for a discourse and related policy incentives.

The biofuel analysis conducted in this thesis shows that niche technology expectations are not used exclusively by niche network actors but may also be used by coalition actors, albeit in a different manner. An example visible in both the Dutch and the Swedish niche experiments and discourses is the promise of biofuel as a means to reduce emissions. However, in order to influence policy it is not sufficient to 'voice expectations', as is argued by some SNM scholars. Based on evidence from the biofuel analysis, and in line with discourse perspective, influencing policy is a complex process which involves successful strategic management of the discourse and beneficial contextual conditions in order for a discourse to gain sufficient legitimacy to influence policy in a direction that contributes to niche development.

Yet there is additional empirical evidence that strengthens the argument that more effort is required than niche expectations alone if protection in terms of policy instruments is to be generated. This refers to the observation that biofuel discourses have a strong impact on biofuel expectations and experimentation, while the impact of biofuel experiments and expectations on discourses is hardly visible. In this thesis an example of the influence of discourses on expectations is the withdrawal of the Swedish methanol discourse and the termination of funds that followed in the mid-1980s, despite positive methanol expectations. A Dutch example is the inability of positive conventional biofuel expectations to gain support in the 1990, because the bioenergy and advanced biofuel discourses hampered conventional biofuel discourse development, resulting in temporary and very limited policy protection of conventional biofuels. The strong impact of discourses on local technology niche expectations is also supported by others, such as Geels and Raven (2006) in their analysis of biogas development in the Dutch energy sector.[97] An example from the biofuel case studies of a niche expectation that had visible impact on discourses was the failure of Nedalco to build an ethanol plant, an outcome which led to the withdrawal of positive ethanol expectations and the disappearance of ethanol from the conventional biofuel discourse. This was mainly because Nedalco, which ran the ethanol project, was the leading discourse actor.

The limited visible impact of local niche expectations on discourses in the Swedish and Dutch biofuel cases does not necessarily mean that lessons and related expectations were not picked up in discourses. However, it is likely to be a general pattern in the case of potentially radical niche technologies since such lessons and expectations represent relatively novel ideas that are subordinated to other more conventional ideas in society. That society is made up of a great number of conventional ideas or discourses explains why coalition actors promoting niche technology discourses face such difficulty in attracting legitimacy. More frequently, there is a need for general discourses to change in a direction which creates opportunities for novel ideas to evolve into discourses. Examples of crucial

[97] The effect of discourses on expectations is particularly visible in Geels and Raven (2006) in the case of the Promest centralized biogas plant in the early 1990s, which despite warnings and negative lessons from local niche actors was up-scaled as a result of strong support from agricultural regime actors. The general influence of discourses on local expectations is acknowledged in their finding that local biogas niche expectations are generally dependent on external (regime) problems such as high energy prices and climate change.

events that created changes in the discourse context which benefitted biofuel discourse developments were the oil crisis in Sweden, the EU Common Agricultural Policy reform in the Netherlands and the EU Biofuel Directive in both countries. Taken together, strategic actions by niche advocates and events creating opportunity for change could be interpreted as creating space for the development of a 'policy niche'. This observation supports the idea that there is not only a need for space at the socio-technical innovation level; there is also a need for space at the policy level in order for a technology niche to come about.

The empirical findings and theoretical discussion on the impact of discourses on niche expectations have led to more insights regarding the relationship between the expectation and discourse concepts. The SNM idea of expectations emerging from niche experiments and lessons can be complemented by the idea of discourses as an inspiration for new expectations. Moreover, the new policy measures resulting from positive discourse development are likely to influence the direction of search at the niche level, and thus the niche expectations. Based on these observations, Figure 23 shows arrows indicating the weak influence (dotted line) from niche expectations to discourses and strong discourse influence (firm line) on expectations.

Following the reasoning of Smith and Raven (2012), creating discourses for the purpose of policy-related niche protection is more or less difficult depending on how radical the proposed niche development pattern is. They sketch two main development patterns that a discourse might present: a pattern which to a greater extent fits and conforms with conventional practices and rules, and a pattern which increasingly stretches and transforms away from conventional practices with an ambition to change the rules of the game. Biofuels are generally seen as a fit-and-conform technology. This is because they hardly affect people's everyday behaviour with regard to mobility and thus do not question the mobility regime. However, biofuels have a different relation to the fossil fuel regime and the case studies show both fit-and-conform and stretch-and-transform development patterns. The fit-and-conform pattern was visible in the early Swedish methanol case as well as in the early days of the Dutch advanced biofuel discourses. The pattern is visible in the claims that the technologies would become competitive with fossil fuels and that protection would only be temporary. The stretch-and-transform pattern has been increasingly visible for conventional biofuel discourses and in the more recent advanced biofuel discourses. These discourses recognize a higher cost for these fuels, but argue for the need to change in order to reduce the impact of climate change. One indication of such an ongoing rule change is the implementation of sustainable criteria to steer the fuel market towards more sustainable fuel solutions. The empirical examples show that biofuel coalition actors have proposed more radical discourse patterns in recent years, which is likely to be related to the increased urgency around emission reductions in the transport sector and thus a more beneficial general discourse context.

While Smith and Raven (2012) address the ways in which coalition actors deal with the resistance of dominant discourses, many transition scholars (Loorbach, 2010; Loorbach & Rotmans, 2010; Voss & Kemp, 2006) address a variety of governance manuals which policymakers can use in order to facilitate transitions.[98] However, according to Weber and Roracher (2012), these transition policies will not work in practice since the current innovation policies are not equipped to deal with them as they are mainly aimed at generating innovation and economic growth. Hence, they suggest the introduction of new governance routines which change the basic routines and values of the conventional innovation system in order to facilitate transitions. Weber and Roracher stress the fact that the routines of the policy

98 See Chapter 1 for a more elaborate discussion of the governance of sustainable transitions.

system also rest on dominant discourses and institutions that prevent novel technology discourses from gaining ground and generating policy support.

The discussion has provided insights into the way in which the discourse and SNM concepts overlap. I suggest below how some elements of this overlap can be dealt with. This may provide the basis for future, more elaborate work on a combined framework.

First, the overlap between the niche network and discourse coalition could be resolved by structuring them according to Smith and Raven's (2012) idea of 'inward oriented activities' and 'outward oriented activities', which is partly based on the idea outlined in the introduction of how local and global niche activities interact and generate niche development. Niche networks can be defined as local networks carrying out 'inward oriented network activities aimed at the practical development of a socio-technical configuration', while discourse coalition can be seen as global networks carrying out 'outward oriented activities of representing, promoting and enrolling support for that development' (Smith & Raven, 2012: 1031-1032). According to Smith and Raven (2012), these networks are protected and part of the niche. Empirical evidence shows that actors do not need to choose between the two networks, but can participate in both at the same time. Moreover, the division of actors carrying out inward- and outward-oriented activities will also clarify some of the overlap between expectations and discourses. While expectations are visible at both the local and the global network (coalition) levels, discourse theory and empirical evidence indicate that expectations alone will not result in policy protection. Strategic activities involving discourse creation are required, coupled with a beneficial discourse context, which calls for these activities to be defined as outward oriented. Other similarities between expectations and discourses, such as the attraction of network actors and giving direction to niche development, are more difficult to define as either inward- or outward-oriented activities.

The Swedish and Dutch biofuel case studies show that there are relationships between the innovation and policy niches, but to what extent these finding can be generalized is too early to say. The biofuel case is rather specific, showing that development would not have come about without protection in terms of policy instruments. More empirical evidence is needed to develop a framework for analysing the development of innovation and policy niches, preferably on contrasting cases. One example of the additional issues that need to be investigated in order to develop a fruitful combination of the niche and policy analytical frameworks is whether and, if so, how the MLP perspective should be integrated. As is outlined above, MLP and the discourse perspective have overlapping functions – they both aim to define power and the dominant forces in society which resist change. Moreover, policy instruments are not the only means of protection that influence the development of the niche. Hence, it may also be of interest to look at how to address the dynamics of other protection types, such as the use of a market with selection criteria different from that of the regime or the generation of niche stability through niche internal processes. The analysis has shown that policy dynamics cannot be isolated from these types of shielding. An example of market shielding generated by the policy process is the regulation by the Swedish government which banned further expansion of the natural gas pipeline in order to shield biogas market expansion. Policy processes also generate policy instruments (subsidies, regulations, etc.) that enable the creation of stability through internal niche dynamics.

To conclude this discussion, the discourse analysis shows the complexity of policy dynamics which a conventional SNM perspective ignores. The same lacuna can be recognized in other transition perspectives such as the MLP and TIS. In addition, the SNM and other transition perspectives choose not to explain the dynamics of policy protection and their influence on transitions. By revealing the dynamics of the policy process, discourse analysis not only contributes to transition analytical perspectives but can also contribute to the development of more suitable policy instruments to steer the transition in a desired direction.

In addition to the contribution of the discourse perspective to transition theory, the way in which transition and discourse analytical perspectives have been coupled in this thesis can also make contributions to discourse theory. The study of policy processes in relation to innovation processes is new not only in the transition field, but also in the field of policy science. Although many discourse scholars stress the way in which discourses are translated into practice in everyday life, and thus influence actors' behaviour (see introduction), this is seldom analysed (Kern, 2010: 57-58). In this thesis, the biofuel policy (protection or non-protection) resulting from the policy process is translated into socio-technology practices in terms of niche actors' expectations, experiments and learning processes. Hence, a theoretical framework that complements SNM with an analysis of the policy process might be a future framework of interest not only for transition scholars, but also for policy scientists.

This analysis and discussion has opened up roads for new theoretical developments in the field of transition theory and provided the basis for a new transition framework that takes policy dynamics into account.

Epilogue

The analysis shows successful and large scale biofuel development and implementation in Sweden, largely due to a policy process which has resulted in generous policy protection. However, the pace and degree of conventional biofuel implementation says nothing about the sustainability of the biofuels implemented. If we are to believe the more recent scientific findings presented as part of the anti-biofuel discourse, conventional biofuels do more harm than good. This takes account of not only their negative environmental effects, but also their socio-economic effects. Large scale investment in conventional biofuels in particular has been criticized by the anti-biofuel discourse. In Sweden, resistance to suggested EU and government policies which would phase out conventional ethanol subsidies is already visible (Lantmännen, 2012; Energimyndigheten, 2013). This resistance could be interpreted as a Swedish ethanol lock-in when it comes to the alternative fuel market.

From an SNM perspective, Sweden's large scale implementation of a potentially unsustainable technology alternative such as conventional ethanol could be interpreted as a result of overprotection. Seen from this perspective, the more restricted Dutch policy support, mainly geared towards R&D development of advanced biofuels coupled with very high demands on sustainability, could result in more sustainable alternative fuel outcomes in the long term. The implementation of conventional biofuels in the Netherlands has been more or less forced by EU policy, and precautions were taken to prevent potential lock-in that would hamper future, more sustainable fuel solutions. One potential shortcoming of Dutch policy, which prioritizes the best and most sustainable fuel options, is that it might result in a wait-and-see approach that produces no solutions at all since new and more promising alternatives may always be just around the corner.

In defence of the Swedish approach, the fact that some conventional biofuel feedstock, production processes and combustion techniques are less sustainable than others would not have been discovered without these biofuel experiments. Despite the heavy criticism of biofuels in the late 2000s, Swedish biofuel practices have faced only limited criticism. Moreover, Sweden has recognized and adjusted to the criticism by promoting the development and use of more sustainable biofuels. Seen in a wider context, researchers at Chalmers Technical University (personal communication, 2008) argue that the large scale Swedish ethanol project should be seen as part of a larger learning process towards more sustainable technology development. They argue that ethanol development has created political pressure and environmental spin-offs, such as reduced emissions from diesel fuel cars and a growing interest in electric vehicles (ibid.). Moreover, Swedish policy has never indicated that a static conventional ethanol market would be the end goal – the policy has promoted a market which would facilitate the implementation of more advanced and sustainable biofuels when they are sufficiently mature. Advanced biofuel development has always been supported alongside conventional biofuel market creation. While policy has consistently promoted advanced biofuel development, technological immaturity has prevented large scale implementation. Hence, there are technological barriers to the realization of more sustainable and advanced biofuel technologies and also limits on how much Sweden is willing to subsidize.

The analysis also shows that there are different approaches to sustainable fuels and what type of policy best stimulates sustainable fuel development and implementation. The Dutch community has been more hesitant about the sustainability of biofuels than the Swedish, which is partly reflected in the different degree of policy support. However, despite the reorientation of EU policy away from promoting biofuels alone in the Biofuel Directive to promoting various alternative fuels in the Renewable Energy Directive, biofuels remain an important part of the EU CO_2 reduction target of 10% by 2020, and both Sweden and the

Netherlands see biofuels as a necessary means to reach this target. This implies that most parties still agree that biofuels have environmental benefits, although some have more than others.

Currently, both Sweden and the Netherlands see sustainability as important and use sustainable criteria or other quality standards to assure high-level CO_2 reductions when alternative fuels, such as biofuels, are implemented. However, while the Netherlands and increasingly also the EU (EC, 2009; EC, 2012) promote regulative and market-orientated policy instruments, such as biofuel implementation quotas and double-counting measures, Sweden has promoted tax exemptions and other subsidy-based protection to a larger degree. According to the Swedish Energy Authority (Energimyndigheten, 2013), this is the only means to attract the long-term commitment of market players and develop more advanced biofuels.

The Swedish policy approach fits with the SNM and transition literature in general, because it sees the need to create long term protected space to enable a co-evolution of novel technology, the market and regulative structures. The temporary protection in terms of market orientated policy instruments used in the Dutch case does not create long-term space for experimentation, which is likely to result in actors searching for quick fixes that to a larger extent result in less sustainable solutions. However, overprotection can also result in unsustainable solutions and should be prevented. According to the transition literature, the stimulation of variety and reflexive learning enables sustainable development. While the Netherlands may have been too restrictive regarding space for biofuel experimentation it is the only case that shows a clear example of reflexive learning. The particularly critical Dutch perspective on biofuels and enforced biofuel implementation by the EU meant that the Netherlands was one of the first EU member states to develop sustainability criteria, and to seek to enforce similar developments at the EU policy level.

In the end, we have to remember that policy is constructed through a policy process. It is a balancing act of various perspectives and interests. The different approaches in Sweden and the Netherlands are partly a result of different ideas about which policy measures are more appropriate – subsidies or market instruments. They are also a result of the various actors' broader beliefs and interests, influenced by natural resources, industrial and political structures and ongoing policy processes, which steer policy towards the promotion of one fuel development trajectory above another. In the Netherlands, the reluctance to invest in conventional biofuels and interest in advanced oil-based alternatives has largely been steered by national economic interests connected to the petrochemical industry in Rotterdam harbour. In Sweden, the alternative fuel agenda has been influenced by the lack of fossil fuel resources and the availability of large biomass resources suitable for ethanol production.

Appendix A: Informant interviews

Dutch informants:

Date	Organization	Informant	Interviewer
27.01.2007	Eindhoven University of Technology	(Advanced) biofuel expert and project manager	Ulmanen, Johanna
18.06.2007 10.10.2005	Solar Oil Systems, company specialized in PVO[99]	Manager	Ulmanen, Johanna Suurs, Roald
20.02.2008	Platvorm Duurzame Mobiliteit (Platform Sustainable Mobility)[100]	Platform chair	Ulmanen, Johanna
XX.10.2005	Province of Rotterdam	Manager ethanol FFV trial	Ulmanen, Johanna
18.06.2007	Samenwerkings-verband Duurzame Energie (SDE)[101]	(Advanced) biofuel expert and project manager	Ulmanen, Johanna
30.07.2010	Eindhoven University of Technology	Researcher	Ulmanen, Johanna
11.07.2008	TNO	Biofuel expert	Van der Meer, Gijs
18.10.2005	Nedalco, alcohol production company	Biofuel project manager	Suurs, Roald
05.10.2005	Climate Neutral Gaseous and Liquid Energy Carriers (GAVE)	Employee	Suurs, Roald
23.10.2006	Ministry of Housing, Spatial Planning and the Environment (VROM)	Biofuel expert	Suurs, Roald
23.01.2006	Dutch Economic Affairs (EZ)	Biofuel expert	Suurs, Roald
01.05.2006	Energy Reserach Centre of the Netherlands (ECN)	Biofuel policy expert	Suurs, Roald
28.11.2005	Biofuels BV, company specialized in HTU	Manager	Suurs, Roald

Swedish informants:

Date	Organization	Informant	Interviewer
12.11.2007	Chalmers University of Technology	Biofuel expert	Ulmanen, Johanna
08.11.2007	Chalmers University of Technology	Advanced biofuel expert	Ulmanen, Johanna
16.11.2007	Chalmers University of Technology	Sustainable energy expert	Ulmanen, Johanna
23.11.2007	Chalmers University of Technology	Sustainable energy expert	Ulmanen, Johanna
XX.02.2008	Royal Institute of Technology (KTH)	Energy technology and policy historian	Ulmanen, Johanna
14.09.2007	Umeå University	Ethanol historian	Ulmanen, Johanna

99 Mainly focus on rapeseed oil production and use in vehicles.

100 Platform part of the energy transition policy of the Dutch Economic Affairs.

101 Organization for collaboration between public and private parties in the field of industrial research towards sustainable energy solutions.

Appendix B: Key projects and meetings visited

Date	Location	Meeting
2004-2009	Eindhoven, the Netherlands	Recurrent meetings of the Technical University of Eindhoven bioenergy and biofuel group
7-11.05.2007	Berlin, Germany	15th European Biomass Conference & Exhibition
20-21.11.2006	Leeuwarden, the Netherlands	Energy Valley, Conference on Sustainable Mobility
21.11.2006	Petten, the Netherlands	Energy Reserach Centre of the Netherlands (ECN) - Demonstration of R&D on gasification technology and related FT-processes.
23.11.2005	's-Hertogenbosch, the Netherlands	Province of Brabant, Expert Meeting Biofuels (Expertmeeting Biobrandstoffen) - part of setting the agenda for biofuel development in the Province of Brabant.
16.11.2005	Eindhoven, The Netherlands	Platform Bioenergy – Business Meeting Biofuels (Platvorm Bioenergie – Business Meeting Biobrandstoffen)
7.6.2005	Eindhoven, the Netherlands	Ingenia - Workshop ‘Platform Biofuels the Netherlands’ (Platform Biobrandstoffen Nederland)
17.02.2004	Utrecht, the Netherland	GAVE (Climate Neutral Gaseous and Liquid Energy Carriers) Network Day

References

Aan de Burgh, M. (2007, March 31). 'We verbranden gigantisch veel voeding'. Sterke toename van gebruik biobrandstoffen zet voedingsindustrie onder druk door hoge prijzen. *NRC Handelsblad*.

Aberson, H. (11-21-2011). PPO (Pure Plant Oil) - revisited! Solaroilsystems. Internet Communication

Abrahamson, H. (1975). Volvo kör redan tio bilar med metanol i tankarna. *Ny Teknik, 1975,* 1,18.

AD (1992, May 23a). Eerste vier auto's op biodiesel de weg op; Nieuwe brandstof dringt milieuverontreiniging terug. *Algemeen Dagblad*.

AD (1992, June 26b). Motorstoring. *Algemeen Dagblad*.

AD (1992, April 30c). Oneens over alcohol tanken; Bio-ethanol in auto minder duur dan rapport zegt. *Algemeen Dagblad*.

AD (1992, May 6d). Proef met bus op bio-alcohol in Groningen. *Algemeen Dagblad*.

AEGPL (2010). AEGPL Europe. Homepage AEGPL [online]. Available: www.aegpl.eu

AGD (2005, May 6). Twentsche oliemolen will eind 2005 koolzaad persen. *Agrarisch Dagblad*.

AGD (2007, May 20). Connexxion laat kwart Friese bussen op biodiesel rijden. *Agrarisch Dagblad*.

Agenschap NL (2012). Duurzame energie in Nederland (DEN). Homepage EZ [online]. Available: www.agentschapnl.nl/programmas-regelingen/duurzame-energie-nederland-den

Ahlbäck, A. (2003). *The evolution and functionality of the branch development project Biogas Väst: an innovation system approach. MA thesis.* Environmental System Analysis Chalmers University of Technology, Göteborg.

Ahlmark, P. and Johansson, O. (2-23-1978). Om energiforskning m.m. Regeringens proposition 1977/78: 110.

Ahlvik, P. (2002). *Metanoldrivna bilar i Trollhättan - Göteborg. Förstudie.* (Rep. No. Vinnova 2002:06).

Ahlvik, P. and Brandberg, Å. (2002). *Med hållbarhet i tankarna. Introduktion av biodrivmedel.* (Rep. No. Vägverket 2002:83). Borlänge: Vägverket.

Aldén, B., Eklund, A. and Larsson, T. (2002). *Flottförsök med GTL diesel - framtidens drivmedel för dieselfordon.* Länsstyrelesen Västernorrland Län.

Alpman, Marie (2012, June 26). Etanolfabriken i Örnsköldsvik hotas av nedläggning. *Ny Teknik*.

Alternativbränsleutredningen (1996). *Bättre klimat, miljö och hälsa med alternativa drivmedel - Betänkande av Alternativbränsleutredningen.* (Rep. No. SOU 1996:184.). Stockholm: Fritzes.

ANP (1994, February 24). Europese subsidie voor Rotterdamse verkeersprojecten. *Algemeen Nederlandse Persbureau ANP*.

ANP (1995, June 7). Plezierboten op biodiesel. *Algemeen Nederlandse Persbureau ANP*.

ANP (1998, August 17). Shell en Daimler-Benz samen in ontwikkelen schone waterstofauto. *Algemeen Nederlands Persbureau ANP*.

Arends, M. (2007). Biovalue puts first biodiesel factory into use in Eemshaven. *Biovalue. New generation biodiesel*.

Avelino, F. (2011). *Power in transitions: Empowering discourses on sustainability transitions.* Rotterdam: Erasmus University of Rotterdam.

Azar, C. (2006a). Christian Azar: Biodrivmedelstvång en bra strategi för lägre koldioxidutsläpp. *Miljörapporten*.

Azar, C. (2006b). Christian Azar: Bioenergins roll i den globala energiomställningen. *Miljörapporten*.
Azar, C. (2007). Christian Azar: Kan certifikat lösa bioenergins problem? *Miljörapporten*.
BD (1995, October 25). EU steunt proef met negen stadsbussen - Bussen in Rotterdam jaar lang op biodiesel. *Brabants Dagblad*.
Bengtsson, S. (2005). Nytt fokus i energipolitiken. *Energimagasinet, 7,* 6.
Bengtsson, Staffan (2007). Förgasat biobränsle kan ersätta naturgas. *Energimagasinet, 6,* 56-58.
Bengtsson, S. (2008). *Sixth Framework Programme. Priority 6.1: Chrisgas fuels from biomass. Executive Summary.* (Rep. No. Project no. 502587).
Bengtsson, W. (1991). Sveriges energipolitik på väg mot en ny katastrof? *Energimagasinet, 2*.
Benjaminsen, TA., Bryceson, I., Dahlberg, A. et al. (2009, April 14). Svenskt bistånd ska rädda miljöfarligt etanolprojekt. *Dagens Nyheter*.
BER (2009). BER kiest voor bio-LNG. Homepage BER [online]. Available: www.ber-rotterdam.com
Berg, R. (1997a). *BioEtanolbussar i Skaraborg. Slutrapport.* (Rep. No. KFB 1997:14). Stockholm: Kommunikationsforskningsberedningen.
Berg, R. (1997b). *Blandbränsle etanol/diesel.* (Rep. No. KFB 1997:35). Kommunikationsforskningsberedningen.
Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S. and Rickne, A. (2008). Analyzing the functional dynamics of technological innovation systems: a scheme of analysis. *Research Policy, 37,* 407-429.
Bertilsson, B.-M., Brandberg, Å., Pilo, C., Laveskog, A. and Isaksson, K. (1986). *Användning av alternativa drivmedel. Teknikbeskrivning och probleminventering.* (Rep. No. STU-project 85-5300). Stockholm: STU.
BEST (2006). Rotterdam is the first spot in the Netherlands to put E85 bioethanol on the fuel market. Homepage BEST [online]. Available: www.best-europe.org/Pages/ContentPage.aspx?id=58
BEST (2009). Pumps for renewables subsidised in the Netherlands. Homepage BEST [online]. Available: www.best-europe.org/upload/BEST_documents/info_documents/BEST_News_3.pdf
BEST (2010). *BioEthanol for Sustainable Transport. Results and recommendations from the European BEST project.* Environmental and Health Administration, City of Stockholm on behalf of the BEST Cities and Regions.
Biewinga, E. E. and Van der Bijl, G. (1996). *Sustainability of energy crops in Europe. A methodology developed and applied.* Utrecht: Centre for Agriculture and Environment (CLM).
Bijker, W. E., Hughes, T. P. and Pinch, T. J. (1987). *The social construction of technological systems. New directions in the sociology and history of technology.* Cambridge Mass: MIT Press.
Bijlsma, J. (2002, December 20a). De oliemolen 3: Locatiekeuze: wie van de drie? *Bizz*.
Bijlsma, J. (2002, October 19b). Wordt vervolgd (1): Olie in de autotank. *Bizz*.
Bijlsma, J. (2002, November 15c). Wordt vervolgd (2): De oliemolen. *Bizz*.
Bijlsma, J. (2003, August 22a). De oliemolen (11): Gaat het Zuiden er met de primeur vandoor? *Bizz*.
Bijlsma, J. (2003, September 19b). De oliemolen (12): Ontstaat er voldoende chemie tussen de aandeelhouders? *Bizz*.
Bijlsma, J. (2003, October 17c). De oliemolen (13): Klanten, klanten, klanten. *Bizz*.
Bijlsma, J. (2003, November 21d). De oliemolen (14): Aanloop naar de aandeelhoudersvergadering. *Bizz*.
Bijlsma, J. (2003, February 21e). De oliemolen (5): Met olie de consumentenmarkt veroveren? *Bizz*.

Bijlsma, J. (2003, March 21f). De oliemolen (6): Wat doen de Duitsers? *Bizz.*
Bijlsma, J. (2003, July 18g). De oliemolen 10: Doen de landbouwers het of doen ze het niet? *Bizz.*
Bijlsma, J. (2004, January 23). De oliemolen (16): Happy end? *Bizz.*
Bildt, C. and Wibble, A. (1993). Förslag till statsbudget för budgetåret 1994-95. Bilaga 1: Finansplanen. Prop.1993/94:100.
Bio-nett (2009). *Biofuels handbook. Best practice tools and pilot projects. Produced as part of the Bio-nett project.* Bio-nett.
Biobased Innovations (2012). Transitiehuis ter ondersteuning biobased economy. Homepage Biobased Innovations [online]. Available: www.biobasedinnovations.nl/index.php?option=com_content&task=view&id=177&Itemid=47
Biofuels B.V. (2008). Producten overzicht. Homepage Biofuels B.V. [online]. Available: www.plantaardige-olie.nl/producten.html
Biogas Väst. (2008). Biogas: a strategic choice. Göteborg, Sweden., Business Region Göteborg, Biogas Väst.
Biogas Öst (2009). *Biogas Öst. Projektplan 2009-2012.* Energikontoret i Mälardalen.
Biogas Öst. (2011). Gastankställen. Fem goda exempel. Biogas Öst.
Biomassaforum (2012). Het Energie Onderzoek Subsidie programma (EOS) is bedoeld om de technische kennis over energie-efficiency en duurzame energie uit te breiden. Homepage Biomassaforum [online]. Available: www.biomassaforum.nl/archive-detail.asp?news_id=12
Biopact Bioenergy news (2007). Dutch propose biofuels sustainability criteria: NGOs sceptical, developing world says 'green imperialism'. Biopact Bioenergy News [online]. Available: news.mongabay.com/bioenergy/2007/04/dutch-propose-biofuels-sustainability.html
Biosulfurol Energy (2010). Biosulfurol Energy FAQ. Homepage Biosulfurol Energy [online]. Available: biosulfurol-energy.com/technology/faq.htm
Birath, K. and Pädam, S. (2010). *Clean vehicles in Stockholm. Historic retrospect1994-2010.* The Environment and Health Administration in the City of Stockholm.
Björsell, M. (2004). *Skattebefrielsen för biodrivmedel - leder den rätt? En ekonomisk utvärdering av etanol som biodrivmedel.* (Rep. No. Rapport 5433). Naturvårdsverket.
Blomquist, J. (2006). Ecobränsle blir först... men Perstorp blir störst. *Svensk Frötidning.*
Boerderij (2006, March 28). Koolzaadvereniging opgericht. *Boerderij.*
Boerrigter, H., Calis, H. P., Slort, D. J. and Bodenstaff, H. (2004). *Gas cleaning for integrated biomass gasification (BG) and Fischer-Tropsch (FT) systems: experimental demonstration of two BG-FT systems.* (Rep. No. ECN-RX--04-041). Petten, Amsterdam: Energy research Centre of the Netherlands (ECN), Unit ECN Biomass; Shell Global Solutions International.
Boerrigter, H. and Zwart, R. W. R. (2004). *High efficiency co-production of Fischer-Tropsch (FT) co-production and Substitute Natural Gas (SNG) from biomass.* (Rep. No. ECN-C--04-001). ECN Biomass.
Bosch, N. (2002). Love me Tender. Het subsidieprogramma GAVE. *Duurzame Energie, February 2002,* 48.
Bosker, F. (2002, March 6). Rijden op koolzaadolie oppepper voor economie Noorden. *Leeuwarder Courant.*
Bouchie, L. (4-1-2007). Press release. Royal Nedalco signs agreement to license technology to Mascoma for lignocellulosic ethanol. American-Dutch technology partnership to

explore collaborative research to accelerate commercialization of lignocellulosic ethanol. Cambridge, MA, Mascoma Corporation.

Bouten, J. (2009, August 22). Telen tegen de stroom in. *Energieboerderij*.

Bovag (2005, September 30). Zero-e wil schone tankeilanden. *De Bovag Krant.nl*.

Brandberg, Å. (1981). Därför bör vi satsa på metanol! *Energimagasinet, 1981,* 31-32.

Brandberg, Å., Johansson, L. and Sävbark, B. (1994). *Introduktion av FFV-bilar*. (Rep. No. KFB 1994:11). Stockholm: Kommunikationsforskingsberedningen.

Brandberg, Å. and Sävbark, B. (1994). *Fossila och biobaserade motoralkoholer. Statusrapport*. (Rep. No. KFB 1994:1). Kommunikationsforskningsberedningen.

Brandel, M. (1994). *Biobaserade drivmedel. Förslag till fortsatt inriktning av KFBs demonstrationsprogram*. (Rep. No. KFB-Information 17-1994.). Stockholm: Kommunikationsforskningsberedningen.

Bremen, A.-H. (1991). Intresset stort hos oljebolaget men svagt från bönderna. *Energimagasinet, 1991*.

Brolin, L., Carlsson, B. and Kullbjer, T. (1997). *Linköpings innerstadsbussar på biogas. Uppföljning t o m Juni 1997*. (Rep. No. KFB 1996:99). Stockholm: Kommunikationsforskningsberedningen.

Brolin, L., Hagelberg, M. and Norström, A. (1995). *Biogas som drivmedel för fordon*. (Rep. No. KFB 1995:3). Stockholm: Kommunikationsforskningsberedningen.

Brolin, L., Rudholm, H. and Eklund, P. (1997). *Biogasdrivna fordon i Uppsala*. (Rep. No. KFB 1997:39). Stockholm: Kommunikationsforskningsberedningen.

Brundtland, G. H. et. al. (1987). *Our common future*. (Rep. No. UN General Assembly document A/42/427). UN/World Commission on Environment and Development (WCED).

BTG (2006). Pyrolysis. Homepage BTG [online]. Available: www.btgworld.com/technologies/pyrolysis.html

Bucksch, S. and Egebäck, K.-E. (1999). The Swedish program for investigations concerning biofuels. *The Science of the Total Environment, 235,* 293-303.

Buddingh, Hans (1991, March 20). Na de boerenopstand: de Groene Revolutie. *NRC Handelsblad*.

Cargill (2011). Cargill completes acquisition of Royal Nedalco. Hompage Cargill [online]. Available: www.cargill.com/news/releases/2011/NA3042680.jsp

Carlsson, I. and Molin, R. (1991). *Om energipolitiken*. (Rep. No. Regeringens proposition 1990/91: 88.).

Carlsson, I. and Nygren, J. (1994). Ny lag om skatt på energi m.m. Prop. 1994/95:54.

Change (2008, October 1). Je ruikt kip uit de uitlaat. *Change, 4*.

Chemrec. (7-14-2008). Press information: The European RENEW project releases final scientific report about the future of liquid bio fuels: Chemrec process for renewable fuels most energy- and cost efficient with more than 95% reduction in CO2 emission. Chemrec.

Chemrec. (9-18-2009). Press release: Swedish world premiere for a novel automotive fuel from the forest. Chemrec.

Chemrec (2012). Report from the bio-DME plant in Piteå. Perfectly clean BioDME flowing steadily. Chemrec News May 2012 [online]. Available: www.chemrec.se/Report-from-the-Bio-DME-plant-in-Pite%C3%A5.aspx

Choren (2009). Press Releases. Change in CHOREN's ownership structure and capital increase. Homepage Choren [online]. Available: www.choren.com/en/choren_industries/information_press/press_releases/?nid=208

Christensen, L. (2005). *Formering för samhandling. Framväxten av Biofuel Region. Ett samarbete mellan ISA, NUTEK, VINNOVA.* (Rep. No. Visanu 2005:7). Stockholm: Nutek Förlag.

Clark, G. (2007). Friends of the Earth call for EU to scrap biofuel target. Biofuel Review: international biofuels update daily. [online]. Available: www.biofuelreview.com/content/view/1191/

Correljé, A. and Verbong, G. (2004). The transition to natural gas. In B.Elzen, F. Geels and K. Green (eds), *System Innovation and the Transition to Sustainability: Theory, Evidence and Policy.* (pp. 114-135). Cheltenham UK: Edward Elgar.

Cramer, J. (2006). *Criteria voor duurzame biomassa productie. Eindrapport van de projectgroep "Duurzame productie van biomassa".* (Rep. No. Task Force Energietransitie).

Cramer, J. (2007). *Toetsingskader voor duurzame biomassa. Eindrapport van de projectroep "Duurzame productie van biomassa".* (Rep. No. Energie Transitie).

Cramer, J. (10-13-2008a). Biobrandstoffendoelstelling. Tweede Kamer. DGM 2008099192, Ministerie van VROM.

Cramer, J. (2008b). Opiniestuk van minister Jacqueline Cramer, minister van Ruimte en Milieu, dat op vrijdag 9 mei 2008 is geplaatst in Het Financieele Dagblad. Homepage Ministerie van VROM [online]. Available: www.vrom.nl/pagina.html?id=35912

Croezen, H. and Kampman, B. (2005). *Op de weg met plantenolie? De technische, milieu-hygiënische en kostengerelateerde aspecten van plantenolie als voertuigbrandstof.* (Rep. No. Report 2GAVE-05.05). Utrecht: CE, Senter Novem.

Crone, F. (5-22-2001). Motie van het lid Crone, 27 400 IXB. Vaststelling van de begroting van de uitgaven en de ontvangsten van het Ministerie van Financiën (IXB) voor het jaar 2001. Tweede Kamer der Staten-Generaal, Vergaderjaar 2000-2001. 27400 IXB, nr. 33.

Crutzen P.J., Mosier A R, Smith K.A. and Winiwarter W. (2007). N2O release from agro-biofuel production negates global warming reduction by replacing fossil fuels. *Atmospheric Chemistry and Physics Discussions,* 11191-11205.

Daey Ouwens, K. (1993). Wordt biomassa belangrijkste energiebron? *Duurzame Energie, December 1993,* 10-13.

Daey Ouwens, K. (2007). Wegen naar een Duurzame energievoorziening. In K.Daey Ouwens (ed.), *Energievraagstuk oplosbaar!* (Amsterdam: Paddington.

Daey Ouwens, K. (2002). Biomassa: moeizame, maar krachtige marktintroductie. *Stromen, June 28, 2002.*

Dahlquist, Hans (2009, August 3). Rivstart för Scanias etanolbussar. *Ny Teknik..*

DE (1996). Vergassing is uit, pyrolyse is in. *Duurzame Energie, August 1996,* 38.

DE (1999). HTU-Installatie: olie uit biomassa mogelijk. *Duurzame Energie, December, 1999,* 34.

DE (2001). Koolzaadteelt niet effectief tegen CO2 uitstoot. *Duurzame Energie, June 2001,* 38-39.

DE (2002a). EU staat accijnsvrije biobrandstof nog niet toe. *Duurzame Energie, Juni 2002,* 33.

DE (2002b). Frietboot vaart weer. *Duurzame Energie, December, 2002,* 37.

De Goeij, C. (2007, April 25). Productie biodiesel Kampen stilgelegd. *Nieuw Kamper Dagblad.*

De Gruijl, D. (2006, June 16). Alleen gemeenten zijn dol op biobrandstoffen. *De Stentor/Zwolse Courant.*

De Jager, D., Faaij, A. P. C. and Troelstra, W. P. (1998). *Kosten-effectiviteit van transportbrandstoffen uit biomassa.* Utrecht, the Netherlands: NOVEM (EWAB).

De Jong, F. (1994). *Gas geven. Geschiedenis van BK-GAS B.V. 1954-1994.* Den Haag/Eindhoven: Stichting Historie der Techniek.

De Jong, M. (2001, May 18). Proef met accijnsvrije biodiesel. *Leeuwarder Courant.*

De Nie, L. H. (1992, May 7). Milieu gebaat bij bio-ethanol als motorbrandstof. *Algemeen Dagblad.*

De Provinciale Milieufederaties and Stichting Natuur en Milieu (2008). *Heldergroene biomassa.* Utrecht: De Provinciale Milieufederaties and Stichting Natuur en Milieu.
De Vries (1996). Biodiesel: Commercieel success? *Duurzame Energie, Juni, 1996,* 13.
De Vries, S., Hansen, S. and Van Vaals, M. (2004). *Factbook biobrandstoffen.* Hoofdproductschap Akkerbouw (HPA), Rabobank.
Den Uil, H., Bakker, R. R., Deurwaarder, E. P., Elbersen, H. W. and Wiesmann, M. (2003). *Conventional Bio-Transportation Fuels. An update.* (Rep. No. Report 2, GAVE-03.10). Utrecht: ECN / NOVEM.
DFE (1981). *Energiforskning 1981-84. Information om de statliga forsknings och utvecklingsinsatserna* (Rep. No. DFE 41). Stockholm: DFE.
DFE (1982). *Alternativa drivmedel. En utvärdering av statens FoU-tjänster.* (Rep. No. DFE 48). Stockholm: DFE.
Didde, R. (1997, October 11). De auto gaat rijden met een glaasje op. *De Volkskrant.*
Didde, R. (2002, September 18). OPEK in de polder; Klomp: 'Het ruikt alleen wat naar patat rond de uitlaat.' Veldhuizen: 'Ik gebruik de olie trouwens ook om friet in te bakken.'. *De Volkskrant.*
DN (2005, February 9). Noordelijke voedingsindustrie voedt biobrandstoffabriek. *Dagblad van het Noorden.*
DN (2006, June 10). We hebben de remmende voorsprong van ons aardgas. *Dagblad van het Noorden.*
DN (2007, November 4). Eerste biodieselfabriek draait op volle toeren. *Dagblad van het Noorden.*
Doornbosch, R. and Steenblik, R. (2007). *Biofuels: Is the cure worse than the disease? OECD Round table of sustainable development 2007.* OECD.
Dosi, G. (1982). Technological paradigms and technological trajectories. *Research Policy, 11,* 147-162.
Dynova (2012). Energie Onderzoek Subsidie (EOS). Homepage Dynova [online]. Available: www.dynova.nl/subsidieadvies/energie-onderzoek-subsidie-eos/
EC . (11-26-1997). Energy for the future: Renewable sources of energy, White paper for a community strategy and action plan. COM(97)599 final, Communication from the Commission.
EC. (10-13-1998). Relating to the quality of petrol and diesel fuels and amending Council Directive 93/12/EEC.
Directive 98/70/EC.
EC. (5-17-2003a). On the promotion of the use of biofuels or other renewable fuels for transport. Council Directive 2003/30/EC.
EC. (10-27-2003b). Restructuring the Community framework for the taxation of energy products and electricity. Council Directive 2003/96/EC.
EC (2005). *Persbericht. Aanmaningen van de Europese Commissie aan de lidstaten die niet tijdig uitvoering geven aan de Europese regelgeving over biobrandstoffen.* (Rep. No. IP/05/318). Brussels.
EC. (1-10-2007a). Biofuels progress report. Report on the progress made in the use of biofuels and other renewable fuels in the Member States of the European Union. COM(2006) 845 final, Communication from the Commission.
EC. (1-10-2007b). Renewable energy road map. Renewable energies in the 21st century: building a more sustainable future. COM (2006) 848 final, Communication from the Commission., 1-20.
EC. (2007c). Staatssteun / Nederland. Steunnummer NN 59/2006 ex N 568/06. Accijnsvrijstelling Pure Plantaardige Olie, Coöperatie Carnola. C(2007) 439.

EC. (4-23-2009). On the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. Council Directive 2009/28/EC.

EC. (10-12-2012). Proposal for a Directive of the European Parliament and of the Council. Amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable sources. COM(2012) 595 final.

ECN. (2007). Schoner biogas brengt groene diesel stap dichterbij. ECN Nieuwsbrief, 30 oktober 2001 .

ECN (2008a). Fischer-Tropsch synthesis for synthetic fuels. ECN website [online]. Available: www.ecn.nl/bkm/r-d-programma/bio-transportbrandstoffen-en-raffinage-processen/fischer-tropsch/

ECN (2008b). MILENA gasification process. Homepage ECN [online]. Available: www.ecn.nl/fileadmin/ecn/units/bio/Leaflets/b-08-021_MILENA.pdf

ECN (2011). Milena. Status of Development. Website ECN [online]. Available: www.milenatechnology.com/milena-gasification-technology/

Ecobränsle (2009). Ecobränsle. Hompage Ecobränsle [online]. Available: www.ecobransle.se

Ecobränsle (2012). Ecobränsle. Homepage Ecobränsle [online]. Available: www.ecobransle.se/om-ecobransle

Ecopar (2008). Ecopar AB. Homepage Ecopar [online]. Available: www.ecopar.se/

EEA (2004). *Energy subsidies in the Europena Union: A brief overview.* (Rep. No. EEA Technical Report , 1/2004). Copenhagen: European Environmental Agency, EEA.

EEB (2002). Biofuels not as green as they sound. EEB Position Paper on the Draft Directive on the promotion of the use of biofuels for transport and the Draft Directive amending Directive 92/81/EEC with regard to the possibility of applying a reduced rate of excise duty on certain mineral oils containing biofuels and on biofuels, COM (2001) 547. Homepage: European Environmental Bureau [online]. Available: www.eeb.org/publication/2002/EEB-POSITION-PAPER-ON-BIOFUELS-FINAL-21-May.pdf

EEB (2006). Members - the Netherlands. Homepage European Environmental Board [online]. Available: www.eeb.org/members/netherlands.htm

EET (2001). *Het Hydrothermal Upgrading proces (HTU) voor biomassa liquefactie.* Utrecht, the Netherlands: Samenverkingsverband HTU and EET.

Egebäck, K.-E. and Westerholm, R. (1997). *Miljöpotentialen hos de alternativa drivmedlen biogas, etanol, metanol, naturgas, rapsmetylester och dimetyleter.* (Rep. No. KFB meddelande 1997:4). Stockholm: Kommunikationsforskningsberedningen.

Ekelund, M., Svensson, T., Einang, P.-M., Ekeborg, T., Blückert, I. and Losciale, M. (1993). *Nordiska GasBuss Projektet, Projekt II, Slutrapport mm.* Ecotraffic R&D AB.

Ekelund, M. (1997). *"Svenol" slutrapport. Prov med 7 etanoldrivna lastbilar.* (Rep. No. KFB rapport 1997:20.). Stockholm: Kommunikationsforskingsberedningen.

Ekelund, M. (1998). *From Prototype to Product. The development of low emission natural gas and biogas buses.* (Rep. No. KFB 1997:19). Stockholm: Kommunikationsforskningsberedningen.

Elbersen, H. W., Kappen, F. and Hiddink, J. (2002). *Quickscan hoogwaardige toepassingen voor rest- en nevenstromen uit de voedings- en genotmiddelenindustrie. Een rapport voor LNV-I&H.* (Rep. No. 01/213). Wageningen: ATO B.V.

Energie Cités (1999). *Biogas - Biofuel. Stockholm Sweden.* Energie Cités.

Energieraad (2007). Nieuwsbericht: Nederlandse biodieselproducenten verenigen zich. Homepage Energieraad [online]. Available: www.algemene-energieraad.nl/newsitem.asp?pageid=1544

Energigas Sverige (2011). Sammanställning över antal gasfordon, gastankställen och såld gasvolym i Sverige 1995 till 2010. Homepage Gasbilen, Fordonsgasutvecklingen i Sverige [online]. Available: www.gasbilen.se/Att-tanka-pa-miljon/Fordonsgas-i-siffror/~/media/Files/www_gasbilen_se/Att-tanka-pa-miljon/FordonsgasISiffror/Allasiffror2010.ashx

Energikontoret Skåne (2005). *Biogas Syd - ett samverkansprojekt mellan regionala biogasintressenter. Ambition och Vision 2005-2015.* (Rep. No. December, 2005).

Energimagasinet (1980). Olof Palme: Gör inte bilbränsle av de fattigas mat! *Energimagasinet, 1980,* 51.

Energimagasinet (1999). Etanol-fabrik för drivmedel i Norrköping. *Energimagasinet, 4,* 17.

Energimagasinet (2007). Storsatsning på etanolforsking. *Energimagasinet, 7,* 7.

Energimyndigheten (2011). *Hållbarhetskriterier för biodrivmedel och flytande biobränsle.* (Rep. No. *Version 2, 2011*).

Energimyndigheten (2013). *Yttrande angående EU kommissionens förslag angående indirekt förändrad markanvändning* Eskilstuna: Energimyndigheten.

Energy transition (2009). Transition platform Green Feedstock. Homepage SenterNovem [online]. Available: www.senternovem.nl/energietransitiegg/transitiepaden/index.asp

Energy Valley (2008). Energy Valley. Mission. Homepage Energy Valley [online]. Available: www.energyvalley.nl/index.php?option=com_content&task=view&id=210&Itemid=154

Engström, O. and Hellström, M. (1990). Om livsmedelspolitiken. Proposition 1989-90:145.

Engwerda, J. (2007, April 3). Ecoson is meer dan een experiment. *Agrarisch Dagblad.*

Engwerda, J. (2011, April 21). Carnola gaat graan vermarkten. *Agrarisch Dagblad.*

Eriksson, L. and Rehnlund, B. (2008). *RME, en översiktlig genomgång.* Miljöbilar i Stockholm.

EU (2007). *Press Release: Transport, Telecommunications and Energy. Council of the European Union.* (Rep. No. 2782nd Council Meeting (Provisional version)). Brussels.

EU (12-17-2008). European Parliament legislative resolution of 17 December 2008 on the proposal for a directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources (COM(2008)0019 - C6-0046/2008 - 2008/0016(COD)). P6_TA-PROV(2008)0609.

Evers, C. (1997, March 22). Biodiesel ten onrechte in kwaad daglicht. *Leeuwarder Courant.*

Evers, C. (1998, May 20). Experiment met biodiesel is mislukt. *Leeuwarder Courant.*

EVN (1993). Advies SER: Gebruik agrarische transportbrandstoffen. Thema: Overheid en Energiebeleid 1993. Energie Verslag Nederland, EVN [online]. Available: www.energie.nl/

EVN (1996). Ruwe olie uit biomassa. Thema: Techniek en onderzoek, 1996. Energie Verslag Nederland, EVN [online]. Available: www.energie.nl

EVN (1997a). DME als brandstof. Thema: Techniek en onderzoek 1997. Energie Verslag Nederland, EVN [online].

EVN (1997b). Projecten in het kader van het CO2 reductieplan. Thema: Overheid en energiebeleid, 1997. Energie Verslag Nederland, EVN [online]. Available: www.energie.nl

EVN (1998). Accijnsvrijstelling voor bio-ethanol, in: Energie Verslag Nederland, Thema: Olieproducten en raffinaderijen, 1998. Energie Verslag Nederland, EVN [online]. Available: www.energie.nl

EVN (2002). Nieuw subsidieprogramma: Klimaatneutrale Gasvormige en Vloeibare Energiedragers (GAVE) 2002. Thema: Overheid en energiebeleid 2002. Energie Verslag Nederland, EVN [online]. Available: www.energie.nl

EVN (2005). Duurzame Energie 2005, Biobrandstoffen. Energie Verslag Nederland, EVN [online]. Available: www.energie.nl/
EZ (2003). *Visie op biomassa. De rol van biomassa in de Nederlandse energievoorziening 2040.* (Rep. No. 03/37). Den Haag: Ministerie van Economische Zaken.
EZ (2004). *Energietransitie: stand van zaken en het vervolg. Innovatie in the energiebeleid.* Den Haag: Ministerie van Economische Zaken.
Factwise (2009). *SEKAB - etanol till varje pris? Hur SEKABs biobränsleprojekt i Tanzania drabbar lokalbefolkningen.* Action Aid.
Falk, M. (2006). Etanolmarknad värd hundratals miljarder, men... Sverige lämnar walkover i matchen? *Tidningen Skogsvärlden,* 2.
Fallde, M., Flink, M., Lindfeldt, E., Pettersson, K. and Wetterlund, E. (2007). *Bakom drivmedelstanken - Perspektiv på svenska biodrivmedelssatsningar.* (Rep. No. Arbetsnotat Nr.36). Program Energisystem - Arbetsnota.
Fargione, J., Hill, J., Tilman, D., Polasky, S. and Hawthorne, P. (2008). Land clearing and the biofuel carbon debt. *Science Express, 319,* 1235-1238.
FD (1995, March 8). Biodiesel tijdelijk vrij van accijns. *Het Financieel Dagblad.*
FD (2001, November 29). Procestechnologie niet sexy genoeg. *Het Financiele Dagblad.*
FD (2003, August 1). Noorden krijgt primeur koolzaadpers. *Het Financieel Dagblad.*
Finansdepartementet. (1990). Lag om koldioxidskatt. SFS 1990:582.
Fischer, F. (2003). *Reframing public policy: Discursive politics and deliberative practices.* New York: Oxford University Press.
Fock, J. (2007a). "Bioenergi är inte svaret på allting". *Miljörapporten.*
Fock, J. (2007, November 1b). Lantmännen stoppar RME-fabrik. *Miljörapporten.*
Fock, J. (2007c). Rekord för etanolbilar. *Miljörapporten.*
Fock, J. (2007d). Sekab flyttar etanolproduktion till Afrika. *Miljörapporten.*
Forbes (2007). IMF warns about impact of biofuels on food prices. Forbes.Thomson Financial News Limited 2007 [online]. Available: www.forbes.com/feeds/afx/2007/10/17/afx4229623.html
Forsberg, B. (1972). Pyrolys gör sopan lönsam. Fem "sopkemikombinat" klarar allt svenskt avfal. *Ny Teknik, 1972,* 12-13.
Framtidsbränslen (2008). Framtidsbränslen. Pilotprojekt. Homepage Framtidsbränslen [online]. Available: www.framtidsbranslen.se/
Fuelswitch (2010). Tankstations Nederland. Homepage Fuelswitch [online]. Available: www.fuelswitch.nl/index.php?mod=map
Fuelswitch (2012). Fuelswitch - Voertuigen. Homepage Fuelswitch [online]. Available: www.fuelswitch.nl/index.php?mod=pages&cat=20&item=0
Gallagher Commission (2008). *The Gallagher Review of the indirect effects of biofuels production.* The Renewable Fuels Agency.
GAVE. (4-27-2001a). "This means that we can inform you that it is decided to continue GAVE" (Min. of Environment, 30-01-01). GAVE e-mail 2001, no.1 .
Ref Type: Internet Communication
GAVE. (2001b). Verslag bijeenkomst 'GAVE-klinkt'. GAVe-mail 2001 no.3 .
GAVE. (2002a). ECN onderzoekt de productie van bio-ethanol op basis van biomassa residuen. GAVE-mail 2002, no.7 .
GAVE. (2002b). Europese Commissie wijzigt voorstel stimulering biobrandstoffen. GAVe-mail 2002, no.10 .
Ref Type: Internet Communication
GAVE. (2002c). Gave gaat in op (Europese) beleidsaspecten vloeibare brandstoffen. GAVe-mail 2002, no.8 .

GAVE. (2002d). Mogelijkheden productie Fischer Tropsch brandstof via biomassa vergassing nader onderzocht. GAVE-mail 2002, no.9 .
GAVE. (11-6-2003a). De studie Analyse en Evaluatie van GAVE-ketens (in 1999 gepubliceerd) . GAVe-mail 2003, no.11 .
GAVE. (10-8-2003b). Nieuwe projecten op de GAVE website. GAVe-mail 2003, no.10.
GAVE. (2003c). Opwerking slachtbijproducten voor toepassing in stationaire dieselmotor. GAVe-mail 2003, no.2
GAVE. (2-13-2003d). Presentaties GAVE netwerkdag. GAVe-mail 2003, no.2 .
GAVE. (12-23-2003e). TNO: Bioethanolprijs kan drastisch omlaag. GAVe-mail 2004, no.1 .
GAVE. (11-1-2003f). Truck van McDonalds rijdt op pure plantaardige olie. GAVe-mail 2003, no.12 .
GAVE. (2-13-2003g). Verslag workshop EU-richtlijnen. GAVe-mail 2003, no.2 .
GAVE (2004a). Commerciële HTU-demonstratiefabriek. GAVe-mail 2004, no.6 .
GAVE. (2-11-2004b). ECN successfully produces green gas. GAVe-mail 2004, no.2.
GAVE. (11-30-2004c). Nederland doet verslag aan EC over Biotransportbrandstoffen. GAVe-mail 2004, no.18.
GAVE. (7-6-2004d). Nota Verkeersemissies: meer reacties. GAVe-mail 2004, no.10.
GAVE. (7-7-2004e). Nota Verkeersemissies: reactie ethanolfabrikant. GAVe-mail 2004, no. 10.
GAVE. (4-28-2004f). NRC: schimmelenzym helpt gist houtsuikers verteren. GAVe-mail 2004, no.12.
GAVE. (10-13-2004g). Platform wil snel besluit over invoering biobranstoffen. Gave-mail 2004, no.16.
GAVE. (10-12-2004h). PPO te duur voor Zeeuws-Vlaamse overheid. GAVe-mail 2004, nr.16.
GAVE. (11-1-2004i). Tweede kamer wil stimulering van biobrandstoffen. GAVe-mail 2004, no.18.
GAVE. (7-22-2004j). Zeeuws-Vlaanderen wil nadere studie biodiesel. GAVe-mail 2004, no.11.
GAVE. (8-12-2005a). Coöperatie Carnola krijgt voor 3 miljoen liter accijnsvrijstelling. GAVe-mail 2005, no.11.
GAVE. (2-22-2005b). De Nederlandse biobrandstofinitiatieven. GAVe-mail 2005, no.4.
GAVE. (8-3-2005c). Eerste Nederlandse biodieselfabriek in Emmen of Eemshaven? GAVe-mail 2005, no.11.
GAVE. (9-21-2005d). Eerste reacties op kabinetsplan biobrandstoffen. GAVe-mail 2005, no.13.
GAVE. (3-1-2005e). GAVE publiceert Nederlandse praktijkvoorbeelden biobrandstoffen. GAVe-mail 2005, no.5.
GAVE. (7-14-2005f). Gemeente Leeuwarden gaat biobrandstoffen stimuleren. GAVe-mail 2005, no.10 .
GAVE. (10-12-2005g). Grootste biotankstation Europa in Leeuwarden. GAVe-mail 2005, no.14.
GAVE. (9-21-2005h). Kabinet presenteert plannen stimuleren biobrandstoffen. GAVe-mail 2005, no.13.
GAVE. (8-24-2005i). Milieuorganisaties willen wettelijke voorwaarden voor biobrandstoffen. GAVe-mail 2005, no.12.
GAVE. (7-14-2005j). Nederlands eerste oliemolen; Duitsland overweegt accijnsverlaging. GAVe-mail 2005, no.10.
GAVE. (5-1-2005k). Nederlandse initiatieven. GAVe-mail 2005, no.7.
GAVE. (4-1-2005l). Nederlandse intiatieven. GAVe-mail 2005, no.6.
GAVE. (2005m). Nieuwe praktijkvoorbeelden op de GAVE-website. GAVe-mail 2005 no.13.

GAVE. (10-1-2005o). Nieuwe praktijkvoorbeelden op GAVe-website. GAVe-mail 2005, no.14.
GAVE. (7-1-2005n). Nieuwe praktijkvoorbeelden op GAVe-website. GAVe-mail 2005, no.10.
GAVE. (12-15-2005p). Noord-Brabant: bedrijfsleven en provincie aan de slag met biobrandstoffen. GAVe-mail 2005, no.17.
GAVE. (7-14-2005q). Proef met Brabantse bussen op koolzaaddiesel. GAVe-mail 2005, no.10.
GAVE. (6-6-2005r). Provincie Limburg stimuleert ombouw wagenpark op koolzaadolie. GAVe-mail 2005, no.11.
GAVE. (4-16-2005s). Rotterdam gaat bioethanol tanken. GAVe-mail 2005, nr.5.
GAVE. (8-24-2005t). Shell stapt in tweede generatie biobrandstoffen. GAVe-mail 2005, no. 12.
GAVE. (7-15-2005u). Voor het eerst in Nederland ethanol uit stro geproduceerd. GAVe-mail 2005, no.10.
GAVE. (6-6-2005v). Vrachtauto op puur plantaardige olie. GAVe-mail 2005, no.8.
GAVE (2006a). Bio-ethanol productie in de Amsterdamse Amerikahaven. GAVe-mail 2006, no.8.
GAVE. (2-22-2006b). Plannen voor bio-ethanol fabriek in Rotterdam. GAVe-mail 2006, no.4 .
GAVE. (10-27-2006c). Rotterdam wil 3000 ethanolautos in regio. GAVe-mail 2006, no.23.
GAVE (2007a). Biobrandstoffen in Nederland. Import en distributie van biobrandstoffen. Shell Nederland. Homepage GAVE [online]. Available: www.gave.novem.nl/figuur025/project/voorbeeldii.html#shell1
GAVE. (9-12-2007b). GAVE atlas: update biobrandstofinitiatieven. GAVE nieuwsoverzicht september 2007 .
GAVE (2008). Veelgestelde vragen. De meest gestelde vragen en wetenswaardigheden over biobrandstoffen. GAVE, Senter Novem [online]. Available: www.senternovem.nl/gave/faq/faq_biobrandstof.asp
GAVE (2009a). Biobrandstoffen in Nederland. Biofuels. Homepage GAVE [online]. Available: www.gave.novem.nl/figuur025/project/voorbeeldi.html#biofuels
GAVE (2009b). Biobrandstoffen in Nederland. OPEK. Homepage GAVE [online]. Available: www.gave.novem.nl/figuur025/project/voorbeeldi.html#opek1
GAVE (2009c). Futura Petroleum - Harvest Biofuels. Bio-ethanol facility in Amsterdam. Homepage GAVE, SenterNovem [online]. Available: www.sn-gave.nl/voorbeeld_project_en.asp?projectid=96
GAVE (2009d). Gemeente Venlo. Fleet on clean fuels. Homepage GAVE, SenterNovem [online]. Available: www.senternovem.nl/gave_english/netherlands_initiatives/searchtool/index.asp
GAVE (2009e). Lijst initiatieven. Homepage GAVE, SenterNovem [online]. Available: www.senternovem.nl/gave/nederlandse_initiatieven/totale_lijst_initiatieven/index.asp
GAVE (2009f). Praktijkvoorbeelden biobrandstoffen. Homepage GAVE [online]. Available: www.gave.novem.nl/figuur025/project/voorbeeld.html
GAVE (2011). Nederlands beleid biobrandstoffen. Homepage GAVE, SenterNovem [online]. Available: www.senternovem.nl/gave_english/netherlands_biofuels_policy/index.asp#5
GAVE (2012). Catalogus van Nederlandse biobrandstofiniatieven. GAVE, Senter Novem [online]. Available: www.sn-gave.nl/voorbeeld_all.asp
Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. *Research Policy, 31,* 1257-1274.

Geels, F. W. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research Policy, 33,* 897-920.

Geels, F. W. (2005). The dynamics of transitions in socio-technical systems: A multi-level analysis of the transition pathway from horse-drawn carriages to automobiles (1860-1930). *Technology Analysis & Strategic Management, 17,* 445-476.

Geels, F. W. and Raven, R. P. J. M. (2006). Non-linearity and expectations in niche-development trajectories: Ups and downs in Dutch biogas development (1973-2003). *Technology Analysis & Strategic Management, 18,* 375-392.

Geels, F. W. and Schot, J. (2010). The dynamics of transitions: A socio-technical perspective. In J.Grin, J. Rotmans and J. Schot (eds), *Transitions to Sustainable Development. New Directions in the Study of Long Term Transformative Change.* (pp. 11-104). New York: Routledge.

Gelderlander (1996, August 29). TNO: Bussen op milieuvriendlijke brandstof kan. *De Gelderlander.*

Gemeente Leeuwarden (2007). Omrin marktleider met 6 voertuigen op aardgas. Klimaat Nieuwsbrief Gemeente Leeuwarden [online]. Available: www.leeuwarden.nl/live/attachment.db?221953

Gengler, Lourens (2008). Super efficient biofuel production. BER-Rotterdam shines new light on first generation biofuels. *New Energy Plus.*

Gigler, J. (2004). *Biomass: Green tool for energy transition in the Netherlands.* Ministry of Economic Affairs.

Gigler, J. K. and Van den Heuvel, E. J. M. T. (2004). *Case study: Gaseous and Liquid Energy Carriers, programme (GAVE)* (Rep. No. Altener 2002-157). REACT - Renewable Energy Action.

Gota Verde (2010). Who we are. Gota Verde in brief. PPO Groeneveld. Homepage Gotaverde [online]. Available: gotaverde.org/en_new_portal/node/1

Goudriaan, F. and Naber, J. E. (2008). HTU diesel from wet waste streams. Symposium New Biofuels Berlin - May 2008. 5-1-2008.
Ref Type: Slide

Granvik, M. (1997). *Blandbränsle minskar partikelutsläpp.* (Rep. No. KFB 1997:29). Stockholm: Kommunikationsforskingsberedningen.

Grin, J. (2006). Reflexive modernisation as a governance issue, or: designing and shaping re-structuration. In J.-P.Voss, D. Bauknecht and R. Kemp (eds), *Reflexive Governance for Sustainable Development.* (pp. 57-81). Cheltenham, UK, Northampton, MA, USA: Edward Elgar.

Grin, J. (2010). Understanding transitions from a governance perspective. In J.Grin, J. Rotmans and J. Schot (eds), *Transitions to Sustainable Development. New Directions in the Study of Long Term Transpormative Change.* (pp. 223-319). New York: Routledge.

Grin, J., Rotmans, J. and Schot, J. (2010). From persistent problems to system innovations and transitions. In J.Grin, J. Rotmans and J. Schot (eds), *Transitions to Sustainable Development. New Directions in the Study of Long Term Transformative Change.* (pp. 1-10). New York: Routledge.

Groene Poort (2012). Groene Poort. Organizatie. Homepage Groene Poort [online]. Available: www.groenepoort.nl/content.php?var_content=3

Groeneveld (2005). PPO - Groeneveld. Homepage PPO Groeneveld [online]. Available: www.ppo-groeneveld.nl/web_bio_oil/Groeneveld.html

Gustavsson, L., Börjesson, P., Johansson, B. and Svenningsson, P. (1995). Reducing CO_2 emissions by substituting biomass for fossil fuels. *Energy, 20,* 1097-1113.

Gustavsson, L. and Svenningsson, P. (1996). Substituting fossil fuels with biomass. *Energy Conversation Management, 37,* 1211-1216.

Gylling, J. (1998). Kommunikationer. In (Motion 1998/99:T223 från Kristdemokraterna. ed..

Haegermark, H. (2001). Priorities of energy research in Sweden. In S.Silveira (ed.), *Building Sustainable Energy Systems. Swedish Experiences.* (pp. 163-196). Stockholm: AB Svensk Byggtjänst and Swedish National Energy Administration.

Hajer, M. and Versteeg, W. (2005). A decade of discourse analysis of environmental politics: Achievements, challenges, perspectives. *Journal of Environmental Policy and Planning, 7,* 175-184.

Hajer, M. (2003). Argumentative Diskursanalyze. Auf der suche nach Koalitionen, Praktiken und Bedeutung. In R.Keller, A. Hirseland, W. Schneider and W. Viehöver (eds), *Handbuch sozialwissenschaftliche Diskursanalyse: Band 2: Forschungspraxis, Volym 2* (pp. 128-152). Heidelberg: Springer.

Hamelinck, C. N. and Faaij, A. P. C. (2006). Outlook for advanced biofuels. *Energy Policy, 34,* 3268-3283.

Hamelinck, C. N., Faaij, A. P. C., Den Uil, H. and Boerrigter, H. (2003). *Production of FT transportation fuels from biomass, Technical option, process analysis and optimization, and development potential. March 2003* (Rep. No. Report NWS-E-2003-08). Utrecht, Petten: Copernicus institute, Utrecht University; ECN.

Harrison, P. (2008). EU backs away from biofuel goal. Reuters, UK [online]. Available: uk.reuters.com

Healy, S. A. (1994). The recent European biofuel debate as a case study in the politics of renewable energy. *Renewable Energy, 5,* 875-877.

Heesen, Peter (2011, April 2). In de sla of in de motor? *De Limburger.*

Held, J., Mathiasson, A. and Nylander, A. (2008). *Biogas ur gödsel, avfall och restprodukter - goda svenska exempel.* Svenska Biogasföreningen; Svenskt Gastekniskt Center AB; Svenska Gasföreningen.

Hettema, Halbe (1999, June 25). Friesland heeft een ideaal: de hele pleziervaart op biodiesel. *Leeuwarder Courant.*

Hillbom, C. (1973). Hushållssopor och skog kan förvandlas till olja och gas. Avfall kan ersätta 30% av oljan. *Ny Teknik, 1973,* 1-7.

Hillman, K. M., Suurs, R. A. A., Hekkert, M. P. and Sandén, B. A. (2008). Cumulative causation in biofuels development: A critical comparison of the Netherlands and Sweden. *Technology Analysis and Strategic Management, 20,* 593-612.

Hofman, R. (2006, June 30). Contract ForFarmers en Twentsche Oliemolen. *De Stentor/Gelders Dagblad.*

Hofstra, C. S. (5-22-2001). Motie van het lid Hofstra C.S. 27 400 IXB. Vaststelling van de begroting van de uitgaven en de ontvangsten van het Ministerie van Financiëe (IXB) voor het jaar 2001. Tweede Kamer der Staten-Generaal. Vergaderjaar 2000-2001. 27 400 IXB, nr. 32.

Hogeschool Hanze (2010). Inleiding tanken PPO. PPO tanken. Link at homepage Hogeschool Hanze [online]. Available: www.hanze.nl/NR/rdonlyres/07B1FE28-C490-4B46-AF1E-B8D74CE839FF/0/HoeenwatoverPPOtanken.pdf

Holm, M. (1997). *Etanoldrivna bussar i drift. Resultat från forskning och försök.* (Rep. No. FB 1997:30.).

Honing, E., Voogt, M. H., Harmelink, M. G. M. and Duvoort, G. L. (2002). *Het belang voor EU klimaatbelied voor Nederland.* (Rep. No. RIVM 773001021/2002, project "Energie en Nationaal Klimaatbeleid" VROM). RIVM.

Hoogma, R. (2000). *Exploiting technological niches: Strategies for experimental introduction of electric vehicles.* (vols. 5) Enschede: Twente University Press.
Hoogma, R., Kemp, R., Schot, J. and Truffer, B. (2002). *Experimenting for sustainable transport: The approach of strategic niche management.* London: Spon.
Hultman, A. (2008, December 19). Gasbilar tillbaks hos Volvo. *Svenska Dagbladet.*
HVC (2009). *HVC en duurzame energie.* Alkmaar, the Netherlands.: HVC.
Hådell, O. (2001). *Strategi för alternativa bränslen i vägtransportsektorn.* (Rep. No. Vägverket 2001:109).
Hådell, O. (2005). Politikernas satsning på etanol är dum och kortsiktig. *Miljörapporten.*
Häggqvist, Jon (2009, April 7). Positiva nyheter för SEKAB. *Allehanda.*
IEA (2006). *100% biogas for urban transport in Linköping, Sweden. Biogas in buses, cars and trains. Biogas in society. Information from the IEA Bioenergy TASK 37 Energy from biogas and landfill gas.* IEA.
IEA (2009). *Transport, energy and $C0_2$. Moving towards sustainability.* IEA/OECD.
IEA (2010). *Energy technology perspectives 2010. Scenario and strategies 2050.* IEA/OECD.
IEA (2011). *Technology roadmap. Biofuels for transport.* OECD/IEA.
Industridepartementet. (1983). Bilaga 14: Introduktion av alternativa drivmedel. Regeringen. Med förslag till statsbudget för budgetåret 1983/84. Prop. 1982/83: 100, 120-128.
Interprovincial Overleg (2010). Subsidie voor tankstations met alternatieve brandstoffen. Hompage Interprovincial Overleg [online]. Available: www.ipo.nl/nieuws/subsidie-voor-tankstations-met-alternatieve-brandstoffen
IPCC (2004). *Intergovernmental Panel on Climate Change (IPCC). 16 years of scientific assessment in support of the climate convention.* Geneva, Switzerland: IPCC.
Jacobsson, S. and Lauber, V. (2006). The politics and policy of energy system transformation: Explaining the German diffusion of renewable energy technology. *Energy Policy, 34,* 256-276.
Jacobsson, S. and Bergek, A. (2004). Transforming the energy sector: The evolution of technological systems in renewable energy technology. *Industrial and Corporate Change, 13,* 815-849.
Janse (1996). Stroomopwekking met biomassa levert beste rendement op. *Duurzame Energie, April 1996.*
Jansen, B. (2008). 18 februari 2008: Biocentrale Groene Poort haalt eruit wat erin zit. PZC, published at homepage Groene Poort [online]. Available: www.groenepoort.nl/news.php
Jansen, J. P. and Berends, R. H. (2002). *Large-scale production of biofuels through biomass (co-) gasification and Fischer-Tropsch syntheses.* (Rep. No. TNO-report R 2002/406). Apeldoorn: TNO.
Johansson, P.-O. (1980). *Metanol som drivmedel. Samhällsekonomiska konsekvenser.* Nämden för energiproduktionsforskning.
Jonsson, P. (2007). *Biodrivmedel. En litterraturöversikt.* (Rep. No. VTI rapport 563). Linköping, Sweden.: VTI.
Jordbruksdepartementet (1980). *Etanol ur jordbruksprodukter.* (Rep. No. Ds Jo 1980:7). Liber förlag.
Jumelet, P. (2007). Tegenstanders: biobrandstof is niet schoon. Newsblad Transport [online]. Available: www.nieuwsbladtransport.nl/nieuws/id19308-Tegenstanders_biobrandstof_is_niet_schoon.html
Kahn Ribeiro, S. et al. (2007). Transport and its infrastructure. In B.Metz, O. R. Davidson, P. R. Bosch, R. Dave and L. A. Meyer (eds), *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate*

Change. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.
Kaijser, A. (2001). From tile stoves to nuclear plants: The history of Swedish energy systems. In S.Silveira (ed.), *Building sustainable energy systems: Swedish experiences.* (pp. 57-94). Stockholm: AB Svensk Byggtjänst and Swedish National Energy Administration.
Kampman, B. E., Croezen, H. J., De Keizer, I. and Bello, O. (2003). *Biomassa: tanken of stoken. Een vergelijking van inzet van biomassa in transportbrandstoffen of elektriciteitscentrales tot 2010.* Delft: CE.
Karlberg, L. A. (2006, October 5). Volvo slutar med gasbilar. *Ny Teknik.*
Karlsson, J.-T. and Jalmby, M. (2007). *A short report on 20 years of experience from ethanol buses in the BioFuel Region.* (Rep. No. BEST 2.4).
Kemp, R., Schot, J. and Hoogma, R. (1998). Regime shifts to sustainability through processes of niche formation: The approach of Strategic Niche Management. *TechnologyAnalysis and Strategic Management, 10,* 175-195.
Kern, F. (2010). *The politics of governing 'system innovations' towards sustainable electricity systems.* (PhD thesis ed.) SPRU - Science and Technology Policy Research, University of Sussex.
Kern, F. (2011). Ideas, institutions, and interests: Explaining policy divergence in fostering `system innovations' towards sustainability. *Environment and Planning C: Government and Policy, 29,* 1116-1134.
Kern, F. and Smith, A. (2009). The transitions storyline in Dutch environmental policy. *Environmental Politics, 18,* 78-98.
KFB (1994). *Alkohol och biogas - realistiska drivmedel för bilar, bussar och lastbilar? En presentation av Kommunikationsforskningsberedningens (KFB) insatser när det gäller biobaserade drivmedel.* (Rep. No. KFB Information 1994-10). Stockholm: Kommunikationsforskingsberedningen.
Kignell, J.-E. (1981). *Energikombinat Stockholm-Nynäshamn. Metanol-Bränslegas-Fjärrvärme. Resultat inom NE-projekt 1760 19 Kombinat Nynäs.* Stockholm: Liber Förlag.
Kimman, J. and Soeriowardojo, E. (2009). *Trendrapportage EOS (2005-2008). Een rapportage over de voornaamste trends en effecten sinds de start van EOS.* (Rep. No. UQE0914858). SenterNovem.
Klemann, H. A. M. (2002). *Nederland 1938-1948: economie en samenleving in jaren van oorlog en bezetting.* Amsterdam: Uitgeverij Boom.
Klipp, M. (1998, October 10). Erkenning voor biodiesel Kooij. *Het Parool.*
Knip, K. (1991, October 31). Elsbett zuiniger dan diesel; Nieuw TNO-rapport bevestigt voordelen van de Elsbettmotor en ziet nog ruime mogelijkheden voor verdere ontwikkeling. *NRC Handelsblad.*
Knip, K. (1992, August 8). Vierde gewas moet eenzijdige akkerbouw redden. *NRC Handelsblad.*
Knoppers, R. (2002). Blauwdrukken voor groene brandstof. *Stromen, September 20, 2002,* 5.
Kommissionen mot oljeberoende (2006). *På väg mot ett oljefritt Sverige.*
Kommunikationskommittén (1997). *Ny kurs i trafikpolitiken: Slutbetänkande av kommunikationskommittén.* (Rep. No. SOU 1997:35). Stockholm: Fritzes.
Koneèný, M. (2004). *EU Enlargement and Agriculture: Risks and Opportunities.* Brussels: Friends of the Earth (FoE) Europe.
Koopman, O. (2006, June 8). Vierhouten Vet ziet goud in biodiesel. *De Stentor/Veluws Dagblad.*
Kristenson, M. (1997a). *Grönt ljus för etanoldrivna lastbilar. Resultat från forskning och försök.* (Rep. No. KFB-rapport 1997:31.). Stockholm: Kommunikationsforskningsberedningen.
Kristenson, M. (1997b). *Lyckad satsning på etanoldrift av personbilar. Resultat från forskning och försök.* (Rep. No. KFB-rapport 1997:32.). Stockholm: Kommunikationsforskningsberedningen.

Kullbjer, T. (1995). *Biogasdrivna bussar i Linköping.* (Rep. No. KFB 1995:14). Stockholm: Kommunikationsforskningsberedningen.
Kågesson, P. (2005). Per Kågesson: Etanolrallyt ett oansvarigt slöseri. *Miljörapporten.*
Lagermalm, G. and Luthman, G. (1980). *Det oljelösa samhället. En rapport om teknisk utveckling och forskning för vår energiberedskap.* (Rep. No. THE rapport no. 7).
Lane, J. (2012). Shell busts a move: Builds drop-in biofuels pilot plant in Texas. Biofuels Digest [online]. Available: www.biofuelsdigest.com/bdigest/2012/02/28/shell-busts-a-move-builds-drop-in-biofuels-pilot-plant-in-texas/
Lantmännen (2011). Lantmännen Agroetanol är Sveriges enda storskaliga producent och leverantör av spannmålsbaserad drivmedelsetanol. Homepage Lantmännen Agroetanol [online]. Available: www.agroetanol.se/om-oss/
Lantmännen (2012). Krönika: "Styrmedel måste premiera klimatnytta och satsningar på biodrivmedel". Homepage Lantmännen Energiblogg [online]. Available: lantmannen.se/omlantmannen/press--media/blogg/111/lantmannens-energiblogg/573/kronika-styrmedel-maste-premiera-klimatnytta-och-satsningar-pa-biodrivmedel/
Larsson, E. (1997). *Etanoldrivna stadsbussar i Örnsköldsvik. Projekt Västernorrland. Slutrapport för etapp I, II och III. Med bilagor.* (Rep. No. KFB 1997:36.).
Larsson, P. and Karlsson, M. (2011). *Försäljning av miljöfordon och förnybara drivmedel i Stockholm. Sammanställning av statistik för år 2010,* Miljöbilar Stockholm.
LC (2000, May 22). Grond te duur voor goedkope biodiesel. *Leeuwarder Courant.*
LC (2005, October 18). Rendac: biodiesel uit dierlijk vet. *Leeuwarder Courant.*
LE. (2-12-2008). Connexxion rijdt op biodiesel. Land van Energie .
Ref Type: Internet Communication
Levinthal, D. A. (1998). The slow pace of rapid technological change: Gradualism and punctuation in technological change. *Industrial and Corporate Change, 7,* 217-247.
Lindblom, M. and Landälv, I. (2007). *Chemrec's atomospheric and pressurized BLG (Black Liquor Gasification) technology: Status and future plans.* Stockholm: Chemrec AB.
Lindemalm, C. (2003, December 4). Skaffa mijöbilförmåner och kör på bensin! *Miljörapporten.*
Lindemalm, C. (2004, February 12a). Massiv kritik mot lagförslag om etanoltvång på 2400 mackar. *Miljörapporten.*
Lindemalm, C. (2004, March 4b). Trots försök och satsningar. Kollektivtrafiken långt ifrån grön. *Miljörapporten.*
Lindholm, I. (2005). "Miljöbränlsekravet som hämtat från Sovjet". *Mijörapporten.*
Lingsten, A., Johansson, M., Bjarne, E., Ax, R., Berg, R. and Svensson, R. (1997). *Biogas som drivmedel i fordon. Slutrapport från Trollhätte-projektet.* (Rep. No. KFB 1997:18). Stockholm: Kommunikationsforskningsberedningen.
Little, A. D. (1999). *Analysis and Evaluation of GAVE-chains: Management Summary. Part 1 of 3* (Rep. No. GAVE Report 9921). Utrecht: NOVEM.
LNV, VROM, EZ, BuZa and V&W (2007). *Overheidsvisie op de bio-based economy in the energietransitie: 'De keten sluiten'.* Ministers van: Landbouw, Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer,
Economische Zaken, Ontwikkelingssamenwerking en Verkeer en Waterstaat.
Loorbach, D. (2007). *Transition Management: New mode of governance for sustainable developent.* Utrecht: Erasmus Univarsity of Rotterdam.
Loorbach, D. (2010). Transition Management for sustainable development: A prescriptive, complexity-based governance framework. *Governance: An International Journal of Policy, Administration, and Institutions, 23,* 161-183.

Loorbach, D. and Rotmans, J. (2010). Towards a better understanding of transitions and their governance: A systemic and reflexive approach. In J.Grin, J. Rotmans and J. Schot (eds), *Transitions to sustainable development. New directions in the study of long term transpormative change.* (pp. 105-222). New York: Routledge.

Lothigius, J. (1997). *Biogas för fordonsdrift. Resultat från forskning och försök.* (Rep. No. KFB 1997:33). Stockholm: Kommunikationsforskningsberedningen.

LRF. (2007). 2006 van LRF mång segrar i politiken. LRF.
Ref Type: Pamphlet

Lyondell Chemie Nederland, Port of Rotterdam and Ecofys Netherlands B.V. (2007). *Conversie van het MTBE productieproces naar ETBE op basis van bio-ethanol* (Rep. No. Senter Novem Projectnummer UKR02020). Senter Novem.

Lysen, E. H., Daey Ouwens, C., Van Onna, M. J. G., Blok, K., Okken, P. A. and Goudriaan, J. (1992). *De haalbaarheid can de produktie van biomassa voor de Nederlandse Energiehuishouding* Den Haag: Novem.

Löfvenberg, U. (2007). *Short report from the Swedish experience of using low blend of ethanol derivative in diesel, ED-diesel.* (Rep. No. BEST Deliverable No D3.3 and D3.6). BEST, BioFuel Region.

Macaré, M. S. (2006). *Zijn er nog vragen? Een kwalitatief onderzoek naar vraagarticulatie vanuit energietransitie naar lange termijn energieonderzoek. Master thesis.* Eindhoven University of Technology, Eindhoven, the Netherlands.

Maltesson, H. Å. (1997). *Biogas för fordonsdrift. Kvalitetsspecifikation.* (Rep. No. KFB 1997:4). Stockholm: Kommunikationsforskningsberedningen.

Mared, J. (1990). Naturgasen största hotet någonsin. *Energimagasinet, 4,* 18.

Marx, P. (1999a). Milieuvoordeel van biodiesel ter discussie. *Stromen,* 7.

Marx, P. (1999, October 15b). Olie uit rotte sinaasappels. *Stromen,* 7.

Mellde, R. (1988). Energisnåla bilar - teknik och kostnader. In C.Oettinger (ed.), *Energi och Transporter. Nordisk konferens 18-19 november 1987. Lejondals slott, Stockholm.* (Helsinki: Nordiska Ministerrådet.

Milieudefensie (2005). *Informatieblad Palmolie - Vet fout! Van tropisch bos tot patatje mèt.*

Milieudefensie (2006). Essent schort inkoop palmolie tijdelijk op. Milieudefensie feliciteerd Essent met verstandig besluit. Milieudefensie Homepage, news [online]. Available: www.milieudefensie.nl/globalisering/nieuws/palmoliestopessent/view?searchterm=essent%20palmoliestroom

Milieudefensie (2008). Globalisering. Links Biomassa. Homepage Milieudefensie. [online]. Available: www.milieudefensie.nl/globalisering/links/links-palmolie.htm#NGO

Miljö och Energidepartementet (1989). *Energiforskning för framtiden. Förslag till statligt program den 1 juli 1990 - 30 juni 1993 för forskning inom energiområdet m.m. Bilagor till betänkandet av energiforskingsutredningen EFU 90.* (Rep. No. SOU 1989:49.). Stockholm: Allmänna Förlaget.

Miljöbilar i Stockholm. (2004). Stockholm chooses clean vehicles. Broschyr. Miljöbilar i Stockholm.

Miljödepartementet (2004). *Pressmeddelande. Utredningen om förnybara fordonsbränslen.* (Rep. No. M2003:02).

Miljöfordon (2006). En miljard kronor investeras i ny etanolanläggning i Norrköping. Miljöfordon nyhetsbrev [online]. Available: www.miljofordon.se/nyheter

Miljörapporten (1997a). Rapsdieselns framtid klargörs till våren. *Miljörapporten.*

Miljörapporten (1997b). Statoils rapsmackar hetsar konkurrenter. *Miljörapporten.*

Miljörapporten (1997, June 10c). Svenska Shell: Biobränslen lönar sig inte! *Miljörapporten.*

Miljörapporten (1998a). Björn Gillberg ensam försvarare av metanol. *Miljörapporten.*

Miljörapporten (1998b). Kommunala S-politiker kräver regeringens stöd för miljöarbete. Miljörapporten.
Miljörapporten (1998c). Miljöargument för förnyelse av bilparken. *Miljörapporten.*
Miljörapporten (1998d). Rapsdebatten stoppade Preems storsatsning. *Miljörapporten.*
Miljörapporten (1998, November 27e). SNF gillar etanol. *Miljörapporten.*
Miljörapporten (1999a). Det blir stopp för miljöanpassade drivmedel. *Miljörapporten.*
Miljörapporten (1999b). Regeringsnej till skattebefriande biodrivmedel. *Miljörapporten.*
Miljörapporten (1999c). Skogsvårdslagen ett slag i luften enligt RRV. Nyhetssammanfattning från Miljörapporten Direkt. *Miljörapporten.*
Miljörapporten (1999d). Svagt miljödepartement överkört av finansen. *Miljörapporten.*
Miljörapporten (1999e). Sverige blir demomarknad för Fords FFV-bilar. *Miljörapporten.*
Miljörapporten (2000a). Ingen dispens för etanolinblanding. *Miljörapporten.*
Miljörapporten (2000b). Kärva tider för biodrivmedelsindustrin. *Miljörapporten.*
Miljörapporten (2000c). Miljöanpassad bensin förbjuds - av misstag. *Miljörapporten.*
Miljörapporten (2000d). Skattelättnader för biodrivmedel diskuteras. *Miljörapporten.*
Miljörapporten (2000e). Staten punkterar svensk spetsforskning. *Miljörapporten.*.
Miljörapporten (2001a). Inga pilotprojektdispenser för etanol. *Miljörapporten.*
Miljörapporten (2001, December 7b). Ny anläggning för etanolforsking. *Miljörapporten.*
Miljörapporten (2001, November 15c). Regeringen förlänger skattelättnad för etanol. *Miljörapporten.*
Miljörapporten (2001, October 11d). Saab avvaktar konkreta beslut. *Miljörapporten.*.
Miljörapporten (2001e). Skattebakslag för Ford Focus nästa år. *Miljörapporten.*.
Miljörapporten (2003, April 2a). Biogasbussar intar Stockholm. *Miljörapporten.*
Miljörapporten (2003b). Etanol har stor potential. *Miljörapporten.*
Miljörapporten (2003, April 30c). Etanolsatsning av Roma Etanol och OKQ8. *Miljörapporten.*
Miljörapporten (2003, October 23d). Kampen om det gröna guldet. *Miljörapporten.*
Miljörapporten (2003, April 2e). Lyckad satsning på gasbilar i Göteborg. *Miljörapporten.*
Miljörapporten (2003f). Miljömacktvång möter hård kritik. *Miljörapporten.*
Miljörapporten (2003, May 22g). Nu blandar mackarna i etanol. *Miljörapporten.*
Miljörapporten (2003, August 21h). Skogens guld ska lyfta Norrland. *Miljörapporten.*
Mitchell, D. (2008). *A note on rising food prices.* (Rep. No. 4682). The World Bank.
Moberg, E. (1991). *Naturgas i Sverige - Ett bidrag till diskussionen om statens roll i samhället.* Stockholm: Industriförbundets förlag AB.
Modig, G. (2005). *Black Liquor Gasification: An assessment from the perspective of the pulp and paper industry. Licentiate thesis.* Environmental and Energy Systems Studies, Lund University.
Motoralkoholkommittén (1986a). *Alkoholer som motorbränsle. Slutbetänkande från Motoralkoholkommittén.* (Rep. No. SOU 1986:51). Stockholm: Nordstedts.
Motoralkoholkommittén (1986b). *Förutsättningar för etanolproduktion i en fullskaleanläggning. Betänkande av motoralkoholkommittén.* (Rep. No. I 1985: 02).
Mourik, R. and Raven, R. (2006). *A practioner's view on Strategic Niche Management: Towards a future research outline.* (Rep. No. ECN-E--06-039). ECN.
Mozaffarian, M. and Zwart, R. W. R. (2003). *Feasibility of biomass/waste-related SNG production technologies: Final Report* (Rep. No. ECN-C--03-066). ECN.
Mudeva, A. (2005). Dutch rush to produce biofuel as oil prices surge. Reuters, in Planet Ark news [online]. Available: www.planetark.com/dailynewsstory.cfm/newsid/32047/newsDate/15-Aug-2005/story.htm
Munkhammar, J. (2007). *Försäljning av statliga bolag under tre decennier.* Timbro.

Månsson, T. (1998). *Clean vehicles with biofuel: A State of the Art Report.* (Rep. No. KFB 1998:18). Kommunikationsforskningsberedningen.

Naber, J. E. and et.al. (1999). The HTU process for biomass liquefaction: R&D strategy and potential business development. In Oakland, California: Fourth Biomass Conference of the Americas.

Naturvårdsverket (2011a). Investment Programs (LIP/KLIMP). Homepage Swedsh Environmental Protection Agency. [online]. Available: www.naturvardsverket.se/en/In-English/Start/Legislation-and-other-policy-instruments/Economic-instruments/Investment-Programmes/

Naturvårdsverket (2011b). MIR: Green Investments in Sweden. Homepage Naturvårdsverket [online]. Available: klimp.naturvardsverket.se/mir/submitQuickSearch_en.do;jsessionid=C2FE33D5ECB8A1A5BCFA05BCBD6E85E1

Naturvårdsverket (2012). *Slutredovisning av tankställebidraget. Statligt stöd till åtgärder för främjande av distribution av förnybara drivmedel.* Naturvårdsverket.

Nedalco (2003). *Transitie bio-ethanol. Nr.one. (NedeRland Opweg Naar Ethanol).*

Nelson, R. R. and Winter, S. G. (1977). In search of a useful theory of innovation. *ResearchPolicy, 6,* 36-76.

New Leaf (2009). New Leaf: Energy. Homepage New Leaf Energy [online]. Available: newleaf-energy.co.uk/about/about.htm

NEWNRG (2010). Tank plantaardige olie. Homepage NEWNRG [online]. Available: www.newnrg.nl/index.php?menu=76

Nijland, W. (2012). Nijland Verkeersscholen. Homepage Nijland Verkeersscholen. [online]. Available: www.verkeersschoolnijland.nl/

Nilsson, A. (1984). Vad kör vi på i framtiden? Alla väntar på regeringen. *Energimagasinet, 5,* 20-21.

Norgren, M. (1977). Problem att få fram gas ur avfall. 'Svårt att fortsätta försök med pyrolys'. *Ny Teknik, 1977,* 4.

Norrman, J., Belhaj, M., Arnell, J., Svensén, B. and Larsson, H. (2005a). *Biogas som drivmedel för fordon i Västra Götaland.* (Rep. No. IVL rapport B1615). Stockholm: IVL.

Norrman, J., Belhaj, M., Arnell, J. and Flodström, E. (2005b). *Biogas som drivmedel för bussar i kollektivtrafik.* (Rep. No. IVL).

NRC (1990, June 10). Geen steun voor fabriek motoren met koolzaadolie als brandstof. *NRC Handelsblad.*

NRC (1991, July 11a). Gado laat autobussen rijden op bio-ethanol. *NRC Handelsblad.*

NRC (1991, January 11b). Gado vraagt subsidie voor proef met bussen op alcohol. *NRC Handelsblad.*

NRC (1991, August 23c). Productie van "koolzaad-motor" is vastgelopenin. *NRC Handelsblad.*

NRC (1992, November 14a). Bus in Rotterdam rijdt op 'biodiesel'. *NRC Handelsblad.*

NRC (1992, February 19b). EG wil produktie van biobrandstof stimuleren door accijnsverlaging. *NRC Handelsblad.*

NRLO (1990). *Het gebruik van agrarische produkten voor transportbrandstoffen.* (Rep. No. NRLO-rapport 90/14). Den Haag: NRLO-Werkgroep "Biomassa ten behoeve van energie".

Ny Teknik (1980). Energitekniskt Centrum, Chalmers: El och gas framtidens drivmedel. *Ny Teknik, 1980,* 32-33.

Näringsutskottet (1983). *Om energipolitik.* (Rep. No. NU1982/83: 33).

Näringsutskottet (1988). *Om energipolitik inför 1990-talet. Näringsutskottets betänkande.* (Rep. No. NU 1987/88:40).

OK (2001). OK på väg i 75 år. Bil och oljekooperationen i Sverige. Homepage OK [online]. Available: www.ok.se/Documents/Om%20OK/jubileumsfolder.pdf
Okken, P. A. (1989). Europa moet meer energie uit hout halen. *Duurzame Energie, November 1989,* 16-19.
Omrin (2012). Minder fossiele branstoffen. "Meters maken met de verduurzaming van ons wagenpark". Homepage Omrin [online]. Available: www.omrin.nl/Over_Omrin/Wat_willen_we/Minder_fossiele_brandstoffen.aspx
Oosterheert , R. J. (1993). *Derde hoofdstuk 'Focus' in het Energie Verslag Nederland 1993 - Van verkenning naar beleid.* Energie Centrum Nederland (ECN).
Parool (1996, May 9). Bio-ethanol geschikt als brandstof voor bussen. *Het Parool.*
Paumen, M. (1994, April 22). Plant als fabriek gedijt nog niet. *NRC Handelsblad.*
PBL (2009). Realisatie milieudoelen 2009. Homepage: Planbureau voor de Leefomgeving [online]. Available: www.pbl.nl/nl/publicaties/2009/realisatie-milieudoelen/indicator08.html
Pennewaard, W. (1999, October 13). Ministeries: geen steun biodiesel. *Leeuwarder Courant.*
Pennewaard, W. (2000, February 23a). Einde aan proefproject met biodiesel. *Leeuwarder Courant.*
Pennewaard, W. (2000, March 28b). Provincie Friesland vaart door op biodiesel. *Leeuwarder Courant.*
Persson, G. and Messing, U. (2006). Bugetproposition. Moderna transporter. Prop. 2005/06:160.
Persson, G. and Nuder, P. (2005). Budgetpropositionen för 2006. Förslag till statsbudget för 2006, finansplan, skattefrågor och tilläggsbudget m.m. Prop. 2005/2006:1.
Persson, G. and Ringholm, B. (1999). Förmånsbeskattning av miljöbilar, m.m. Prop. 1999/2000:6.
Persson, G. and Ringholm, B. (2003). Budgetpropositionen för 2004. Förslag till statsbudget för 2004, finansplan, skattefrågor och tillägsbudget m.m. Budgetpropositionen 2003/04:1.
Persson, G. and Sommestad, L. (2005). Skyldighet att tillhandahålla förnybara drivmedel. Prop. 2005/06:16.
Persson, G. and Sundström, A. (1997). En uthållig energiförsörjning. Prop. 1996/97:84.
Persson, G. and Uusman, I. (1998). Transportpolitik för en hållbar utveckling. Prop. 1997/98:56.)
Persson, G. and Åsbrink, E. (1997). Budgetpropositionen för 1998. Prop 1997/98:1.
Persson, K.-E. (1997). Alternativa fordonsbränslen. Motion till riksdagen.
Persson, M., Jönsson, O. and Wellinger, A. (2006). *Biogas upgrading to vehicle fuel standards and grid injection.* IEA Bioenergy. EU BiogasMax.
Perstorp. (11-23-2005). Pressrelease**.** Preem och Perstorp i samarbete om produktion av förnybart fordonsbränsle.
Peterson, T. G. and Lindh, A. (1998). Svenska miljömål. Miljöpolitik för ett hållbart Sverige. Prop. 1997/98:145.
Phillips, N., Lawrence, T. B. and Hardy, C. (2004). Discourse and institutions. *Academy of Management Review, 29,* 635-652.
Platvorm Duurzame Mobiliteit. (6-1-2009). Rijden op groen gas.
Pols, B. (1996, August 24). Nedalco wil grootschalig in bio-brandstof. *NRC Handelsblad.*
Province Drenthe (2007). Boeren en ondernemers bouwen fabriek voor bio ethanol in Wijster. Hompage Province of Drenthe [online]. Available: www.provincie.drenthe.nl/thema/@3762/boeren_en/

Provincies Noord-Nederland (2008). *Het 100.000 voertuigen plan, duurzaam op weg. Toekomst agenda duurzame transportbrandstoffen Noord-Nederland.*
Pädam, S. (2009). *Promoting clean cars: A casestudy of Stockholm and Sweden.* (Rep. No. 5.12). BEST.
Pädam, S., Fenton, P. and Waluszewski, D. (2010). *Försäljning av miljöfordon och förnybara drivmedel i Stockholm. Sammanställning av statistik för år 2009* Miljöbilar Stockholm.
Rahm, L., Brolin, L., Rudholm, H. and Lilja, T. (1997). *Biogas som drivmedel för fordon.* (Rep. No. KFB 1997:37). Stockholm: Kommunikationsforskningsberedningen.
Raven, R. and Verbong, G. (2001). Biomassa. In G.Verbong, A. Van Selm, R. Knoppers and R. Raven (eds), *Een kwestie van lange adem. De geschiedenis van duurzame energie in Nederland.* (pp. 237-276). Boxtel, the Netherlands: Aeneas uitgeverij.
Raven, R. P. J. M. (2006). Towards alternative trajectories? Reconfigurations in the Dutch electricity regime. *Research Policy, 35,* 581-595.
Raven, R. (2005). *Strategic Niche Management for biomass: A comparative study on the experimental introduction of bioenergy technologies in the Netherlands and Denmark.* Eindhoven: Eindhoven University of Technology.
Regeringskansliet (2011). Agenda 21 - en sammanfattning. Homepage Regeringskansliet [online]. Available: www.regeringen.se/content/1/c6/01/86/84/6de2900f.pdf
Rehnlund, B. (2010). Teknisk uppföljning av tunga biogasfordon - Stockholm, Västerås och Arlanda. Miljöförvaltningen Stockholm, Biogas Max.
Rehnlund, B., Blinge, M., Lundin, M., Wallin, M. and Goldstein, B. (2004). *Framtida möjligheter med nya drivmedel. En utvärdering av LIP financierade åtgärder inom alternativa drivmedel.* Naturvårdsverket.
Rehnlund, B. and Van Walwijk, M. (2005). *Assessment of bio-ethanol and biogas initiatives for transport in Sweden.* Atrax Energi.
Reith, J. H. (2004). *Duurzame co-productie van fijnchemicaliën en energie uit micro-algen.* (Rep. No. E.E.T. project K99005/398510-1010). ECN.
Reith, J. H. and de Bont, J. A. M. (2007). *Co-production of bioethanol, lactic acid, electricity and heat from lignocellulosic biomass. Public report EET project KO1116.* (Rep. No. ECN-E--07-045). ECN.
Rennen, C. (2005, November 5). Vrachtwagen op koolzaadolie: puur natuur. *De Stentor/Dagblad Flevoland.*.
Rijschoon (2009). Rijschoon.nu. Maakt schoon autorijden makkelijk. Homepage: Rijschoon.nu [online]. Available: http://rijschoon.wordpress.com
Riksdagen. (12-18-1991). 12 § Skatt på etanol, m.m. Kammarens protokoll 1991/92:48.
Riksdagens Revisorer. (1999). Riksdagens revisorers förslag angående det statliga stödet till lokala investeringsprogram för en ekologiskt hållbar utveckling. Sammanfatting. Skrivelse 1999/2000:RR3.
Riksrevisionen (2011). *Biodrivmedel för bättre klimat. Hur används skattebefrielsen?* (Rep. No. RiR: 2011:10). Stockholm: Riksrevisionen.
Ringström, L. (2003, December 18a). Naturgas - för- och nackdelar. *Mijörapporten.*
Ringström, L. (2003b). Vart leder en naturgasutbyggnad? *Miljörapporten.*
Ringström, L. (2004, September 2). Miljökrav får Saab att lansera etanolbil. *Miljörapporten.*
Ringström, L. (2005a). Hallå, Per Kågesson. *Miljörapporten.*
Ringström, L. (2005b). Massiv RME-inblanding på väg. *Miljörapporten.*
Ringström, L. (2005, September 29c). RME-efterfrågan ger fabrik i Karlshamn. *Miljörapporten.*
Ringström, L. (2007). Biodiesel hotar regnskogen. *Miljörapporten.*
Rip, A. (1995). Introduction of new technology: Making use of recent insights from sociology and economics of technology. *Technology Analysis & Strategic Management, 7,* 417-432.

Rip, A. and Kemp, R. (1996). *Towards a theory of socio-technical change.* Washington, D.C.: Batelle Pacific Northwest Laboratories.
Rotmans, J., Kemp, R. and van Asselt, M. B. A. (2001). More evolution than revolution: Transition management in public policy. *Foresight, 3,* 15-32.
Royal Dutch Shell. (7-15-2008). News and media releases: Shell and Iogen announce extended alliance to accelerate a next generation biofuel. Royal Dutch Shell.
Royal Society (2008). *Sustainable biofuels: Prospects and challenges.* (Rep. No. Policy document 01/08). Royal Society.
Rydén, C. (1994). *Flottförsök med 32 etanolbussar vid AB Storstockholms Lokaltrafik.* (Rep. No. KFB 1994:2). Stockholm: Kommunikationsforskningsberedningen.
Sabatier, P. A. (1999). The need for better theories. In Sabatier P.A. (ed.), *Theoretical lenses on public policy.* (pp. 3-18). Boulder, Colorado.: Westview Press.
Sabatier, P. A. and Jenkins-Smiths, H. C. (1999). The advocacy coalition framework: An assessment. In P.A. Sabatier (ed.), *Theories of the policy process.* (Boulder: Westview Press.
Sabatier, PA. (1988). An advocacy coalition framework of policy changes and the role of policy-oriented learning therein. *Policy Science, 21,* 129-168.
Sabic (2006). SABIC Europe starts production of bio-ETBE in the Netherlands. Homepage Sabic-Europe [online]. Available: www.sabic-europe.nl/news-media-relations/news/_en/start_production.htm
Salomonsson, L. (1983). Metanolens framtid. *Energimagasinet, 5,* 36-37.
Samuelsson, K. (2004, September 23a). ... och etanolens. *Miljörapporten.*
Samuelsson, K. (2004, September 23b). Gas eller etanol? Livscykelanalys väger för och emot. *Miljörapporten.*
Samuelsson, K. (2004, September 23c). Gasens tillskyndare. *Mijörapporten.*
Samuelsson, K. (2004d). Lagstiftning stoppar OKQ8:s försäljning av "miljödiesel". *Miljörapporten.*
Samuelsson, K. (2004e). Politikerna satsar på fel bränslen! *Miljörapporten.*
Samuelsson, K. (2004, November 4f). Statoil prövar metanolinblanding. *Miljörapporten.*
Samuelsson, K. (2004, September 23g). Succé för gratis mijöbilsparkering i Göteborg. *Miljörapporten.*
Samuelsson, K. (2004, September 23h). Svensk etanolproduktion tar fart. *Miljörapporten.*
Samuelsson, K. (2004, January 22i). Svenska etanolproducenter hotas. *Miljörapporten.*
Samuelsson, K. (2004, June 10j). Volvo och Saab förbereder etanolbilar. *Miljörapporten.*
Samuelsson, K. (2004, November 25k). Volvo tar svårstartad etanolbil med ro. *Miljöaktuellt.*
Samuelsson, K. (2005a). Centern svänger i miljöbilsfrågan. *Miljörapporten.*
Samuelsson, K. (2005b). DME och Fischer Tropsch diesel. *Miljörapporten.*
Samuelsson, Kenneth (2005, September 29c). Gasbilarna kan få övertag över etanolbilarna. *Miljörapporten.*
Samuelsson, Kenneth (2005, October 27d). Genombrott för gas i Norrland. *Miljörapporten.*
Samuelsson, K. (2005e). Oförstående till kritiken. *Miljörapporten.*
Samuelsson, K. (2005f). Scania: lönsamma och konservativa. *Miljörapporten.*
Samuelsson, K. (2006a). Kommissionen väntas tillåta 10% etanolinblanding. Miljörapporten [online].
Samuelsson, K. (2006b). Lantmännen miljardinvesterar i energi. Miljörapporten [online].
Samuelsson, K. (2006, April 28c). Scania omvänt: tror på etanolbussar. *Miljörapporten.*
Samuelsson, K. (2007, March 2a). De tävlar om miljödiesel. *Miljörapporten.*
Samuelsson, K. (2007, September 11b). Klartecken för biodiesel anläggning i Piteå. *Miljörapporten.*
Samuelsson, K. (2007c). Kritiserad palmolja miljögranskas. *Mijörapporten.*

Samuelsson, K. (2007d). Läget i Agroetanols fabrik är inte desperat. *Miljörapporten.*
Samuelsson, K. (2007, October 1e). Merparten av biogasen eldas upp. *Miljörapporten.*
Samuelsson, K. (2007f). Palmoljekritik kan hota EU-projekt. *Miljörapporten.*
Samuelsson, K. (2007, October 14g). Problem i portgången för biodiesel. *Miljörapporten.*
Samuelsson, K. (2007, December 7h). Tredje gången gillt för fordonsgasen. *Mijörapporten.*
Sandebring, H. (2004). *Introduktion av förnybara fordonsbränslen.* (Rep. No. SOU 2004:133).
Sandén, B. and Jonasson, K. (2005). *Variety Creation, Growth and Selection Dynamics in the Early Phases of a Technological Transition: The Development of Alternative Transport Fuels in Sweden 1974-2004* (Rep. No. 2005:13). Gothenburg: Chalmers University of Technology.
Schot, J. W., Slob, A. and Hoogma, R. (1996). *De invoering van duurzame technologie: strategisch niche management als beleidsinstrument.* DTO, Ministerie van VROM.
Schot, J. (1992). The policy relevance of the quasi-evolutionary model: The case of stimulating clean technologies. In Rod Coombs, Paolo Saviotti and Vivien Walsh (eds), *Technological Change and Company Strategies* (pp. 185-200). London: Academic Press.
Schot, J. (1998). The usefulness of evolutionary models for explaining innovation. The case of the Netherlands in the nineteenth century. *History and Technology: An International Journal, 14,* 173-200.
Schot, J. and Geels, F. W. (2008). Strategic niche management and sustainable innovation journeys: Theory, findings, research agenda, and policy. *Technology Analysis & Strategic Management, 20,* 537-554.
Schot, J. and Rip, A. (1997). The past and the future of constructive technology assessment. *Technological Forecasting and Social Change, 54,* 251-268.
Schutte, J. R. (2010). Dutch biodiesel producer Biovalue bankrupt. Homepage Energy-Commodities.com [online]. Available: energy-commodities.com/dutch-biodiesel-producer-biovalue-bankrupt/
Schwanbom, A. and Walldén, I. (1981). *Syntetiska bilbränslen och den framtida svenska drivmedelsförsörjningen.* (Rep. No. The-rapport no 8).
Schön, D. A. and Rein, M. (1994). Frame reflection: Towards the resolution of interactable policy controversies. New York: Basic Books.
SDAB (1982). *Tillverkning, hantering och användning av alternativa drivmedel i västeuropa.* (Rep. No. NE 1982:17). Uppsala: Offsetcenter AB.
SDE (2002). *Climate neutral transport fuels from biomass. The BIG-FiT concept. BIG-FiT prelude.* (Rep. No. Projectnumber: P1998-934).
Searchinger, T. et al. (2008). Use of US Croplands for Biofuels Increases Greenhouse Gases through Emissions from Land Use Change. *Science Express, 319,* 1238-1240.
Segers, R. (2011). Verbruik biobrandstoffen in wegverkeer daalt. Homepage CBS [online]. Available: www.cbs.nl/nl-NL/menu/themas/industrie-energie/publicaties/artikelen/archief/2011/2011-04-27-biobrandstoffen-tk8.htm
SEKAB (2008a). E5/Låginblandning. SEKAB homepage [online]. Available: www.sekab.com/default.asp?id=1587&refid=1533&l3=1426 .
SEKAB. (5-26-2008b). Pressmeddelande. Världens första verifierat hållbara etanol till Sverige.

SEKAB (2011a). SEKAB. E85. Homepage SEKAB [online]. Available: www.sekab.com/default.asp?id=1586&refid=1532&l3=1426
SEKAB (2011b). Verifierat hållbar etanol. Ja tack! SEKAB homepage [online]. Available: www.hallbaretanol.se/default.asp?id=1081
Sengers, F., Raven, R. P. J. M. and Van Venrooij, A. (2010). From riches to rags: Biofuels, media discourses, and resistance to sustainable energy technologies. *Energy Policy, 38,* 5013-5027.

Senter (2004). *Effect + resultaat. Jaarverslag 2003*. Ministerie van Economische Zaken.
Senter (2006). EETK01116. Co-productie van bio-ethanol, groene chemicaliën, electriciteit en warmte uit biomassa-(rest)stromen. Homepage EET [online]. Available: www.senter.nl/EET/projecten/Coproductie_van_bioethanol_groene_chemicalien_electriciteit_en_warmte.asp
SenterNovem (2004). *Lange termijn EOS-onderzoeksprogramma's*.
SenterNovem (2005a). EOS Lange Termijn. Een mogelijk nieuwe oplossing voor teerproblemen bij vergassing van biomassa. Homepage SenterNovem [online]. Available: www.senternovem.nl/eos/Projecten/EOS_Lange_Termijn/2005/Een_mogelijk_nieuwe_oplossing_voor_teerproblemen_bij_vergassing_van_biomassa.asp
SenterNovem (2005b). Project KIEM01004 Duurzame benzine en diesel uit biomassa via pyrolyse en het Fischer-Tropsch proces. Homepage E.E.T., SenterNovem [online]. Available: www.senternovem.nl/EET/projecten/Duurzame_benzine_en_diesel_uit_biomassa.asp
SenterNovem (2005c). Project NECST: Toepassing oliewasser voor teerverwijdering uit biomassastookgas (ECN). Homepage EOS, SenterNovem [online]. Available: www.senternovem.nl/eos/infotheek/projectencatalogus/Projecten/eos_nieuw_energieonderzoek/Duurzame_Energie_2/Energie_uit_biomassa/NECST_Toepassing_oliewasser_voor_teerverwijdering_uit_biomassastookgas_(ECN).asp
SenterNovem (2005d). Project: EETK97002 Het hydro-thermal upgrading proces voor biomassa liquefactie. SenterNovem - EET homepage [online]. Available: www.senternovem.nl/EET/projecten/Het_hydrothermal_upgrading_proces_voor_biomassa_liquefactie.asp
SenterNovem (2005e). Project: KIEM01006 ThermoZym, celluloseconversie voor de productie van ethanol. SenterNovem - EET homepage [online]. Available: www.senternovem.nl/EET/projecten/ThermoZym_celluloseconversie_voor_productie_van_ethanol.asp
SenterNovem (2005f). Project: KIEM01012 A radically new approach to the production of bioethanol. SenterNovem - EET homepage [online]. Available: www.senternovem.nl/EET/projecten/A_radically_new_approach_to_the_production_of_bioethanol.asp
SenterNovem (2006a). Energietransitie. Werkgroepen. Homepage Energie Transitie, SenterNovem [online]. Available: www.senternovem.nl/energietransitiedm/werkgroepen/index.asp
SenterNovem (2006b). EOS Demonstratie.Teerverwijdering uit biogas voor toepassing in een gasmotor. Homepage SenterNovem [online]. Available: www.senternovem.nl/eos/Projecten/EOS_Demonstratie/2006/Teerverwijdering_uit_biogas_voor_toepassing_in_een_gasmotor.asp
SenterNovem (2006c). EOS Lange-termijn. Vergassen van natte biomassa in superkritisch water. Homepage SenterNovem [online]. Available: www.senternovem.nl/eos/Projecten/EOS_Lange_Termijn/2006/Vergassen_van_natte_biomassa_in_superkritisch_water.asp
SenterNovem (2007a). Energie Transitie Duurzame Mobiliteit. Project: Dedicated Ethanol Terminal - Vopak. Homepage Energie Transitie, SenterNovem [online]. Available: www.senternovem.nl/energietransitiedm/experimenten/dedicated_ethanol_terminal_vopak.asp

SenterNovem (2007b). EOS Demonstratie Full-scale demonstratie van de OLGA-technologie. Hompage SenterNovem [online]. Available: www.senternovem.nl/eos/Projecten/EOS_Demonstratie/2006/Full-scale_demonstratie_van_de_OLGA-technologie.asp
SenterNovem (2007c). Over Energietransitie. Achtergrond. Homepage Energie Transitie, SenterNovem [online]. Available: www.senternovem.nl/energietransitie/Over_Energietransitie/Achtergrond/Index.asp
SenterNovem (2007d). Project: Het HTU-proces voor hydrothermale liquefactie van biomassa. On homepage Senter Novem. Homepage SenterNovem [online]. Available: www.senternovem.nl/duurzameenergie/projecten/den-projecten_h-hi/het_htu-proces_voor_hydrothermale_liquefactie_van_biomassa.asp
SenterNovem (2008). EOS. Duurzame energie uit biomassa. Simultane productie van biocrude en pyrolysis olie. Homepage SenterNovem [online]. Available: www.senternovem.nl/projecten/eos/simultane_productie_van_biocrude_en_pyrolyseolie.asp
SenterNovem (2009a). Biobutanol: nieuw bioproces voor omzetting lignocellulose in CO2-neutrale transportbrandstoffen, energie en chemicaliën. Homepage SenterNovem [online]. Available: www.senternovem.nl/eos/infotheek/projectencatalogus/projecten/eos_lange_termijn/2006/biobutanol_nieuw_bioproces_voor_omzetting_lignocellulose_in_co2-neutrale_transportbrandstoffen_energie_en_chemicalien.asp
SenterNovem (2009b). MEP: Milieukwaliteit van de Electriciteitsproductie. Homepage SenterNovem [online]. Available: www.senternovem.nl/mep/
SenterNovem (2009c). Project: Bio-ethanol uit bietsuikerpulp: de pectine-uitdaging. Homepage SenterNovem [online]. Available: www.senternovem.nl/eos/infotheek/projectencatalogus/Projecten/eos_lange_termijn/2006/Bio-ethanol_uit_bietsuikerpulp_de_pectineuitdaging.asp
SenterNovem (2009d). Project: Ethanolproductie uit (ligno)cellulosehoudend materiaal. Homepage SenterNovem [online]. Available: www.senternovem.nl/eos/infotheek/projectencatalogus/ethanolproductie_uit_lignocellulosehoudend_materiaal.asp
SenterNovem (2009e). Project: Hoogwaardige grondstoffen en producten uit lignine (LignoValue). Homepage SenterNovem [online]. Available: www.senternovem.nl/eos/infotheek/projectencatalogus/hoogwaardige_grondstoffen_en_producten_uit_lignine_lignovalue.asp
SenterNovem (2009f). Project: N-ergy, microbiologische coproductie van N-chemicals en ethanol uit biomassafracties. Homepage SenterNovem [online]. Available: www.senternovem.nl/energietransitiegg/documentatie/n-ergy_microbiologische_coproductie_van_nchemicals_en_ethanol_uit_biomassafracties.asp
SenterNovem (2009g). Project: Productie van ethanol en andere brandstofalcoholen uit organische zuren in plaats van suikers. Homepage SenterNovem [online]. Available: www.senternovem.nl/eos/infotheek/projectencatalogus/productie_van_ethanol_en_andere_brandstofalcoholen_uit_organische_zuren_in_plaats_van_suikers_.asp
SenterNovem (2009h). Project: Verbeterde hydrolyse van lignocellulose. Homepage SenterNovem [online]. Available: www.senternovem.nl/eos/infotheek/projectencatalogus/Projecten/eos_lange_termijn/2006/Verbeterde_hydrolyse_van_lignocellulose.asp

SenterNovem (2010a). Nederlands biobrandstoffenbeleid. Homepage: SenterNovem, GAVE [online]. Available: www.senternovem.nl/gave/nederlands_beleid_biobrandstoffen/index.asp
SenterNovem (2010b). Tankstations Alternatieve Brandstoffen (TAB). Homepage SenterNovem [online]. Available: www.senternovem.nl/tab/
SKL (2010). Miljömål i kommunerna. Homepage Sveriges kommuner och landsting [online]. Available: www.skl.se/vi_arbetar_med/tillvaxt_och_samhallsbyggnad/miljo/miljomal
SMAB (1977). *Lägesrapport den 10 Februari 1977. Svensk Metanolutveckling AB.*
SMAB (1978). *Methanol as motor fuel: Annual report 1978.* Stockoholm: Svensk metanolutveckling AB.
Smith, A. and Raven, R. (2012). What is protective space? Reconsidering niches in transitions to sustainability. *Research Policy, 41,* 1025-1036.
Spil (1994). SER-advies aanvaard in breder agrificatieperspectief: kabinet rijdt niet op biobrandstof. Brief van Landbouwminister Bukman. *Spil, Deel 1994,* 42-43.
Staatsblad. (10-20-2006). Besluit van 20 oktober 2006, houdende regels met betrekking tot het gebruik van biobrandstoffen in het wegverkeer (Besluit biobrandstoffen wegverkeer 2007). Staatsblad 2006 542.
Starrin, K. (1996). Skattebefrielse på etanol. Motion 1996/97:Sk620 till riksdagen från Centerpartiet.
Statens energimyndighet (2011). *Transportsektorns energianvändning 2010.* (Rep. No. ES 2011:05).
Statens energiverk (1984a). *Energiforskining 1984/85-1986/87. Trädbränslen, torvbränslen, bränsleförädling, elproduktionsteknik, förbränningsanläggningar kolmiljöer.* (Rep. No. Statens energiverk 1984:3).
Statens energiverk (1984b). *Energiperspektiv 1970-95. Problem, Prognoser, Politik.* (Rep. No. Statens energiverk 1984:7).
Statens energiverk (1986). *Motoralkoholer i Sverige. Tekniska och ekonomiska förutsättningar.* (Rep. No. 1986:7). Stockholm: Allmänna Förlaget.
Statens energiverk (1987a). *Gasolboken. Utvinning, hantering och användning av gasol.* (Rep. No. Statens energiverk 1987:6.).
Statens energiverk (1987b). *Naturgas i mellansverige.* (Rep. No. Statens energiverk 1987:5).
Statens energiverk (1989). *Miljöanpassade energiscenarier, Sverige 2015. Bilaga 1 till statens eneriverks och statens naturvårdsverks utredning - Ett miljöanpassat energisystem.* (Rep. No. Statens enerigverk 1989:4.).
Statens energiverk (1990). *1990 Energi - miljö - ekonomi. Bilaga 21 till Långtidsutredingen 1990.* (Rep. No. SOU 1990:14).
Statsrådsberedningen (1999). *Viktigare lagar och förordningar Inför årsskiftet 1999/2000.*
Stegenga, W. (1999, February 27). De PvdA zet Milieu Federatie voor paal. *Leeuwarder Courant.*
Stem (1998, February 20). Nedalco maakt alcohol uit melasse. *De Stem.*
Stern, N. (2006). *Stern Review: The Economics Of Climate Change.* Cambridge: Cambridge University Press.
Stichting Schoner Transport (2007). Duurzaam tankstation in Leeuwarden. Homepage Stichting Schoner Transport [online]. Available: www.energietech.info/schonertransport/delta_oil.html
Stockholms stad (2009). Om Miljöbilar i Stockholm. Uppdrag och mål. Homepage Stockholms stad [online]. Available: www.stockholm.se/Fristaende-webbplatser/Fackforvaltningssajter/Miljoforvaltningen/Miljobilar/Om-Miljobilar-i-Stockholm/Uppdrag-och-mal/

Stockholms stad (2010). Om Miljöbilar i Stockholm. Avslutade projekt. BEST – Bioethanol for Sustainable Transport. Homepage Stockholms stad [online]. Available: www.stockholm.se/Fristaende-webbplatser/Fackforvaltningssajter/Miljoforvaltningen/Miljobilar/Om-Miljobilar-i-Stockholm/Avslutade-projekt/

Stromen (2002a). HTU olie verder. *Stromen,* 6.

Stromen (2002, October 18b). Venlo op koolzaadolie. *Stromen.*

Sundin, B. (2006). Från avfall till möjligheter - etanol i början av 1900-talet. In Erland Mårald and Christer Nordlund (eds), *Polhem Årsbok 2005: Tema: Teknik och miljö* (pp. 65-84). Stockholm: Svenska nationalkomm. för teknikhistoria (SNT).

Sunpine. (6-12-2008). Pressmeddelande: Preem, Sveaskog och Södra satsar på talldiesel. Sunpine.

Sunpine (2010). Världens första talldieselfabrik invigd. Homepage Sunpine [online]. Available: www.sunpine.se/index.php?option=com_content&view=article&id=62-vaerldens-foersta-talldieselfabrik-invigd&catid=35-news&Itemid=55

Suurs, R. A. A. and Hekkert, M. P. (2005a). *Naar een methode voor het evalueren van transitietrajecten. Functies van innovatiesystemen toegepast op 'biobrandstoffen in Nederland'*. Utrecht: Milieu en Natuurplanbureau (MNP) / University of Utrecht.

Svensk biogas (2010). Ansökan om parkeringstillstånd. För privatpersoner som redan är kunder i Svensk Biogas. Homepage Svensk biogas [online]. Available: www.svenskbiogas.se/sb/kundservice/parkeringstillstand/

Svensk biogas (2011). Norrköping. Homepage Svensk biogas [online]. Available: www.svenskbiogas.se/sb/biogas/anlaggningar/norrkoping/

Svensk raps. (1-19-2006). Pressmeddelande: Regeringen möjligör 5% inblanding av RME i all diesel - bra för klimatet luften och för bondens plånbok. Homepage Svensk Raps, Svensk raps.

Svensson, K. (2007). *Förstudie. Sjösättning av Biogas Öst.* Energikontoret Mälardalen..

Swedish Commission for Oil Substitution (1982). *Strategy for alternative fuels.* (Rep. No. Ds I 1982:13).

Swedish Commission of Oil Substitution (1980). *Introduction of alternative motor fuels.* (Rep. No. Industridepartementet Ds I 1980:20).

Swedish Forest Industries Federation (2011). *Så går det för skogsindustrin. Om svenska pappers-, massa- och sågverksindustrin.* (Rep. No. Kvartalsrapport 2011.03). Swedish Forest Industries Federation.

Tamatgreen (2006). Tamatgreen VOF. Gemeente Noord-Beveland op koolzaadolie. Homepage Tamatgreen VOF [online]. Available: www.tamatgreen.nl/article.php?story=20060321101731384

Tamm, D. and Fransso, M. (2011). *Biogasproduktion för miljö och ekonomi. Resultat och erfarenheter av biogasåtgärderna inom Klimatinvesteringsprogrammen (Klimp).* (Rep. No. Naturvårdsverket).

Tandberg, L.-O. (2005). Alternativ till diesel redan här. *Maskin Entreprenören.Sveriges bullrigaste tidning..*

Tatom, J. A. (1993). Are there useful lessons from the 1990-91 oil price shock? *The Energy Journal, 14,* 129-150.

Ten Kate (2010). Ten Kate produceert Lard Oil. Homepage Ten Kate [online]. Available: www.tenkate.nl/nl/news_more.asp?item=1

Thuresson, J. (2006). Socker med smak av blod. *Miljörapporten.*

TNT Post. (6-12-2006). Persbericht. Pakketbezorging door TPG Post in Amsterdam voortaan op biodiesel. TNT Post.

Tonjes, J. (2006, November 24). Naar wens draaiende Twentsche Oliemolen echt open. *Agrarisch Dagblad*.

Trouw (1995, March 18). Milieuvriendelijk op diesel uit koolzaad door Friesland varen. *Trouw*.

Trouw (1997, January 13). Rederij rondvaartboten breidt proef met bio-diesel uit. *Trouw*.

Tubantia (2008, August 26). Over en uit voor Twentsche Oliemolen. Haaksbergen. Vier jaar geleden leek het initiatief een gouden toekomst te hebben. *De Twentsche Courant.Tubantia.*.

Tweede Kamer. (12-16-1996). Beleidsvoornemens op het gebied van Landbouw, Natuurbeheer en Visserij; Brief minister met notitie inzake voortgang van het stimuleringsbeleid rond agrificatie. nr.24140, nr.34. Kamerstuk 1996-1997.

Tweede Kamer. (2001). Milieuprogramma 2002–2005. Tweede Kamer, vergaderjaar 2001-2002, 28 003, nrs. 1-2.

Tweede Kamer. (3-5-2002). Evaluatienota Klimaatbeleid; Nota 'De voortgang van het Nederlandse klimaatbeleid: een evaluatie bij het ijkmoment 2002'. 28240, nr.2. Kamerstuk 2001-2002.

Tweede Kamer. (11-4-2005a). Evaluatienota Klimaatbeleid 2005. Bijlage bij 28240, nr.37, 114.

Tweede Kamer. (9-27-2005b). Wijziging van enkele belastingwetten (Belastingplan 2006); Memorie van toelichting, Kamerstukken 2005-2006. 30306, nr. 3.

Ulmanen, J. H., Verbong, G. P. J. and Raven, R. P. J. M. (2009). Biofuel developments in Sweden and the Netherlands: Protection and socio-technical change in a long-term perspective. *Renewable and Sustainable Energy Reviews, 13,* 1406-1417.

V&W (2008). Nieuwsbericht: 1,8 miljoen subsidie voor landelijk netwerk tankstations alternatieve brandstof. Homepage Ministerie van Verkeer en Waterstaat (V&W) [online]. Available: www.verkeerenwaterstaat.nl/actueel/nieuws/18miljoensubsidievoorlandelijknetwerktankstationsalternatievebrandstof.aspx

Vallander, L., Östman, A. and Wimmerstedt, R. (2006). *Programmet etanol från skogsråvara. Slutrapport.* (Rep. No. ER 2006:23). Statens Energimyndighet.

Van de Beld, L., Van Hutten, R. and Kokke, R. (2004). *Produktie van SNG/CNG via vergassing van natte biomassa in superkritiek water.* (Rep. No. Projectnummer 1162). Biomass Technology Group bv.

Van de Wiel, H. (2006). Kees Daey Ouwens, nestor van de duurzame energie, 'de zon heeft iets met links'. *Milieudefensie Magazine*.

Van den Belt, H. and Rip, A. (1987). The Nelson Winter Dosi model and synthetic dye chemistry. In W.E.Bijker, T. P. Hughes and T. J. Pinch (eds), *The social construction of technological systems: New directions in the sociology and history of technology.* Cambridge Mass: MIT Press.

Van den Broek, R., Van Walwijk, M., Niermeijer, P. and Tijmensen, M. (2003). *Biofuels in the Dutch market: A fact finding study.* (Rep. No. 2GAVE-03.12). Utrecht: Novem, GAVE.

Van den Heuvel, E. J. M. T., De Zeeuw, A. A. and Stuij, B. A. (2000). *Solid shape for gas and liquid: A proposal for a follow-up phase of the GAVE-program aimed at stimulating market development.* (Rep. No. 2GAVE00.05.). Utrecht: NOVEM / GAVE.

Van den Heuvel, E. and Kwant, K. (1996). Bio-ethanol in Nederland. *Duurzame Energie, June 1996,* 10-11.

Van der Knijff, A., Wildschut, L. R. and Williams, A. (1991). Voorlopig nauwelijks ethanol productie uit biomassa. Productie van ethanol uit cellulose is nog in ontwikkeling. *Energie & Milieutechnologie, April, 1991,* 27-31.

Van der Laak, W. W. M. (2005). *Experimenteren met biobrandstoffen in Noord-Brabant. En exploratief onderzoek met behulp van Strategic Niche Management.* Faculteit Technologie Management, Technische Universiteit Eindhoven..

Van der Laak, W. W. M., Raven, R. P. J. M. and Verbong, G. P. J. (2007). Strategic niche management for biofuels: Analysing past experiments for developing new biofuel policies, *Energy Policy, 35,* pp. 3213-3225.

Van der Meer, G. (2009). *Second generation biofuels: The next best thing? Assessment of two second generation biofuels.* Master in Technology and Policy. Energy and Sustainable development. Faculty of Industrial Engineering and Innovation Sciences. Technical University of Eindhoven.

Van der Veen, E. (2003, June 11). Clevering: bestuurder in overall en maatpak. *Dagblad van het Noorden.*

Van der Voort, M. P. J. (2003). *Biobrandstoffen. Een alternatief voor de Nederlandse landbouw.* Wageningen, Praktijkonderzoek Plant and Omgeving, Business-unit Akkerbouw, Groene ruimte en Vollegrondsteelt.

Van Doorn, J. (1993). Transportbiobrandstoffen uit biomassa. *Duurzame Energie, December 1993,* 19.

Van Gelder, J. W. and Kroes, H. (2008). *Subsidies voor biobrandstoffen in Nederland. Een onderzoeksrapport voor Milieudefensie.*

Van Groenestijn, J. W., Hazewinkel, J. H. O. and Bakker, R. R. (2007). *Pre-treatment of ligno-cellulose with biological acid recycling (the Biosulfurol process).* TNO.

Van Kasteren, J. M. N., Dizdarevic, D., Van der Waall, W. R., Guo, J. and Verberne, R. (2005). *Bio-ethanol from bio-syngas.* (Rep. No. 0268040420012).

Van Miltenburg, John (1995, October 2). Elsbett-motor loopt zelfs op frituurvet 'Goed voor de akkerbouw is smerig woord'. *Brabants Dagblad.*

Van Miltenburg, John (1997, April 17). Nedalco krijgt 135 miljoen voor bio-project. *De Stem.*

Van Onna, M. J. G. (1991). *Mogelijkheden van de landbouw om de uitstoot van CO2 te verminderen* (Rep. No. Mededeling 442). Den Haag: Landbouw-Ekonomisch Instituut,LEI.

Van Rhijn, T. (1995, January 2). Friese primeur: Varen op bio-brandstof. *Het Parool.*

Van Roekel, G., Koster, R. and et.al. (2000). *Success en faalfactoren van agrificatie in Nederland* (Rep. No. 607). Wageningen: Agrotechnologisch Onderzoeksinstituut ATO.

Van Rutten, L. H. A. M. (1987). Nog veel problemen bij pyrolyse van afvalstoffen. *Energiebeheer & Afvalbeheer, 1987,* 44-46.

Van Thuijl, E. (2002). *Grootschalige toepassing van biobrandstoffen in wegvoertuigen. Een transitie naar emissiearm vervoer in Nederland.* (Rep. No. ECN-1-02-008). Amsterdam: Technical University of Eindhoven / ECN.

Van Thuijl, E., Roos, C. J. and Beurskens, E. W. M. (2003). *An overview of biofuel technologies, markets and policies in Europe.* (Rep. No. ECN-C--03-008). Amsterdam: ECN Policy Studies.

Van Wijland, G. (2004a). Europese productie biodiesel gestegen, Nederland blijft achter. *Duurzame Energie,* 44.

Van Wijland, G. (2004b). Accijnsverlaging kan biobrandstof concurrerend maken. *Duurzame Energie,* 41.

Van Wijland, G. (2004c). Biodiesel-experiment strandt in Zeeuws-Vlaanderen. *Duurzame Energie,* 39.

Van Wijland, G. (2004d). In afwaching van Nederlands Beleid: fabrikant biodiesel richt sich - vorloopig - op Duitsland. *Duurzame Energie,* 20-21.

Van Wijnand, G. (1999). Trends en cijfers. *Duurzame Energie, December 1999,* 43-45.

Van Zessen, E., Weismann, M., Bakker, R. R., Elbersen, H. W., Reith, J. H. and Den Uil, H. (2003). *Ligno cellulosic ethanol: A second opinion.* (Rep. No. 2GAVE-03.11). Utrect: Novem.

Van Zijl, P. (1981). Afval als grondstof voor autobrandstof. *Beta, 23 Juni, 1981,* 5.

Vanlierop, H. (2001, May 22). Vervoerders gaan van start met accijnsvrije diesel. *Algemeen Nederlandse Persbureau ANP.*

Vedung, E. (2001). The politics of Swedish energy policies. In S.Silveira (ed.), *Building sustainable energy systems. Swedish experiences.* (pp. 95-130). Stockholm: AB Svensk Byggtjänst and Swedish National Energy Administration.

Verbong, G. and Van Selm, A. (2001). Energie als maatschappelijk probleem: het ontstaan en de bewustwording van de energieproblematiek. In G.Verbong, A. Van Selm, R. Knoppers and R. Raven (eds), *Een kwestie van lange adem. De geschiedenis van duurzame energie in Nederland.* (pp. 23-60). Boxtel, the Netherlands: Aeneas uitgeverij.

Vink, M. (2005, September 13). Oliemolen heeft jaarlijks 30.000 ton koolzaad nodig. *De Stentor/Apeldoornse Courant.*

Vink, M. (2006, August 26). Plan voor oliemolen afgeketst. *De Stentor/Gelders Dagblad.*

Vion (2007). Press release: VION subsidiary produces biofuels from abattoir by-products. Ecoson starts production of sustainable biofuels. Vion News at Vion Homepage [online]. Available: www.vionfood.com/pers/pers/97/

Vis, M. (2006). *Beschikbaarheid van reststromen uit de voedings- en genotmiddelenindustrie voor energieproductie : eindverslag.* BTG Biomass Technology Group / NOVEM, DEN-programma.

Volkskrant (1996, May 7). Bio-brandstoffen nuttiger voor maken van stroom. *De Volkskrant.*

Volkskrant (1999, July 1). Friesland vraagt rijk om steun voor bevorderen van biodiesel. *De Volkskrant.*

Volkswagen Group (2008). The eyes of the World are on Freiberg, 17 April 08: First commercial demo. facility for synthetic biofuel in operation. Homepage: Volkswagen Group [online]. Available: www.volkswagenag.com/vwag/vwcorp/content/en/innovation/fuel_and_propulsion/panorama/The_eyes_of_the_world_are_on_Freiberg.html

Voorter, P. (2003, February 14). Biodiesel uit Arnhem. *Stromen, 5.*

Vopak (2005). Vopak - Ethanol. Homepage Vopak [online]. Available: www.vopakbenelux.com/142_414.php

Voss, J.-P. and Kemp, R. (2006). Sustainability and reflexive governance: Introduction. In J.-P.Voss, D. Bauknecht and R. Kemp (eds), *Reflexive Governance for Sustainable Development.* (pp. 3-30). Cheltenham, UK, Northampton, MA, USA: Edward Elgar.

VROM (2001). *Een wereld en een wil: Werken aan duurzaamheid. Natuur en Milieubeleidsplan 4.* (NMP4\2001 047 767 ed.) Den Haag: Ministerie Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, Centrale Directie Communicatie.

VROM. (6-18-2004). Beleidsnota Verkeersemissies. Met schonere, zuiniger en stillere voertuigen en klimaatneutrale brandstoffen op weg naar duurzamheid. VROM 4079 06-04.

VROM (2008). Akkoord richtlijn duurzamheidscriteria biobrandstoffen. Homepage Ministerie van VROM [online]. Available: www.vrom.nl/pagina.html?id=38262

VVBGC (2011). Pressrelease: Svenskt 480-miljoners förgasningsprojekt stoppat. Homepage VVBGC [online]. Available: www.vvbgc.se/index.php/nyheter/3-pressrelease-2011-02-17

Walldén, I. (1975). *Framtida drivmedel: en utredningsrapport av* Sveriges bilindustri- och bilgrossistförening och Motorbranchens riksförbund, Januari 1975.

Weber, K. M. and Rohracher, H. (2012). Legitimizing research, technology and innovation policies for transformative change: Combining insights from innovation systems and multi-level perspectives in a comprehensive 'failures' framework. *Research Policy, 41,* 1037-1047.

Weber, M., Hoogma, R., Lane, B. and Schot, J. (1999). *Experimenting with sustainable transport innovations : A workbook for strategic niche management.* Enschede: Universiteit Twente.

Wempe, J., Jepma, C., Hoogma, R. J. F. and Dumont, M. H. M. (2007, October). Rijden op groen gas. Published letter to the Ministers. Available: www.senternovem.nl/mmfiles/Brief%20aan%20ministers%20over%20rijden%20op%20groen%20gas%20-%2016%20oktober%2007_tcm24-267449.pdf

Werner, H. (1978). Biomassa ger bra mellanvärdegas. Metanolråvara ur snabb pyrolys. *Ny Teknik, 1978,* 12.

Westergård, Per (2006, October 6a). Biogas skåpar ut vindkraft. *Miljörapporten.*

Westergård, Per (2006, October 6b). Bränsleindustrin måste mogna. *Miljörapporten.*

Westergård, P. (2006c). Missionärens teknikval: cellulose. *Miljörapporten.*

Weterings, R., Van Harmelen, T., Gjaltema, J., Jongeneel, S., Manshanden, W., Pollakov, E. et al. (2013). *Naar een toekomstbestendig energiesysteem voor Nederland.* (Rep. No. TNO 2013 R10325). Delft: TNO.

Wiepkema, F.e (1999, October 9). In Nederland wordt het nooit wat met biobrandstof. Reportage Duurzame Energie. *Agrarisch Dagblad.*

Wikipedia (2008). Ecopar. Wikipedia Sweden [online]. Available: sv.wikipedia.org/wiki/Ecopar visited at 30.03.2008

Wikipedia (2010). Folkhemmet. Wikipedia Sweden [online]. Available: sv.wikipedia.org/wiki/Folkhemmet

Wikipedia (2011). Fischer–Tropsch process. Wikipedia [online]. Available: en.wikipedia.org/wiki/Fischer%E2%80%93Tropsch_process

Williander, M. (2006). Fading Eco-benign networks: The causes found at Volvo Car Corporation and Ford Motor Company. *European Journal of Innovation Management, 9,* 92-107.

WUR (2012). Welkom bij Groene Grondstoffen. Homepage Wagening UR [online]. Available: www.groenegrondstoffen.nl/

Zacchi, G. and Vallander, L. (2001). Renewable liquid motor fuels. In S.Silveira (ed.), *Building sustainable energy systems: Swedish experiences.* (pp. 335-366). Stockholm: AB Svensk Byggtjänst and Swedish National Energy Administration.

Zoethout, T. (1997). Nedalco start commerciële productie bio-ethanol. *Duurzame Energie,* 21.

Zwart, R. W. R., Boerrigter, H., Deurwaarder, E. P., van der Meijden, C. M. and van Paasen, S. V. B. (2006). *Production of Synthetic Natural Gas (SNG) from biomass development and operation of an integrated bio-SNG system.* (Rep. No. ECN-E--06-018).

Östling, L., Jonsson, J. Å., Müller, A., Carstedt, P., Eriksson, S. G. and Fransson, G. (2006). Framgång för biodrivmedel kräver rätt pris vid pumpen. *Miljörapporten.*

Östman, A. (1998). *Etanolutvecklingsprogrammet 1993-1997. Slutrapport.* (Rep. No. ER 13:1998). Statens Energimyndighet.

Summary

Finding sustainable solutions for the fossil fuel-based transport sector has been a growing dilemma since the 1970s. One of its most urgent problems is its climate change effects. To substitute fossil fuel use with biofuels is one promising option among many alternative solutions. This is indicated in European Union (EU) policy, which has promoted biofuel production and use since the 1990s, and 2011 fuel statistics showing that 2% of all transport fuels used in the EU were biofuels. However, biofuel use differs significantly among member states. Sweden is considered a front runner (≈5.5% biofuel in 2011), while countries such as the Netherlands have lagged behind (≈2% biofuel use in 2011). Sweden has focused on alcohol-based fuels, both conventional and technically advanced, while the Netherlands has focused increasingly on advanced and vegetable oil-based fuels. This led to the main research question of this thesis: *How can we explain differences in biofuel niche development in Sweden and the Netherlands in the period 1970-2010?*

The differences in biofuel development can be partly explained by natural resource base and industry structure. Sweden's early efforts to develop biofuels are likely to relate to its lack of fossil fuels and large biomass resources and related industry (agricultural and forestry) suitable for alcohol production. In the Netherlands, the lack of biomass and its large petrochemical industry and petrochemical trade are likely to have delayed biofuel development and led to a focus on advanced biofuel products. However, to provide a more elaborate explanation of the differences between Sweden and the Netherlands, such as the timing, nature and patterns of development, a more advanced analysis is needed.

To analyse the research question, this thesis applies a framework grounded in Strategic Niche Management (SNM) theory combined with insights from political science. SNM theory regards the development and market implementation of new and potentially sustainable technologies such as biofuels as dependent on *technological niches*. These niches serve as protected spaces that facilitate the co-evolution of technology, user practices and regulatory structures. However, a weakness in this theory is the limited attention paid to the processes leading up to the creation of protected spaces. In addition, the definition of protection is unclear in the existing literature. SNM and related transition literature generally refer to various financial and regulative policy instruments shielding new technology developments as the main source of protection. Hence, studying policy processes is key to exploring policy-related protection. To gain insight into the way in which policy protection has contributed to different biofuel development trajectories in the different cases, this thesis combines SNM analysis with a discourse analysis of the biofuel policy process. From an interpretative discourse perspective, a discourse is a collection of ideas that influence people's sense-making and behaviour and thus also the political agenda. Discourse theory sees the policy process as a negotiation between opposing discourses, which in turn are triggered by new ideas, interests, events, and so on. Consequently, the analysis applies two analytical perspectives to explain biofuel development. First, an SNM analysis focusing on the concepts: networks that experiment with and implement biofuels, their expectations and the learning processes that explain a biofuel niche development trajectory. Second, a discourse analysis focused on key biofuel discourses, their context, key biofuel discourse coalitions and the activities that influence the development of policy instruments that may or may not protect biofuel development.

The thesis uses this combined framework to analyse the differences between two empirical case studies: Swedish and Dutch biofuel development trajectories. The case studies are based on qualitative research involving three types of sources. The first and main type of source was the wide variety of printed documents, such as books, journal articles, news

items, Internet documentation, statistical records and proceedings from meetings and conferences. The second type was personal communications with selected informants, which complemented the information and filled gaps in the written documentation. The third type involved visits to biofuel projects and attending expert meetings, which provided insight into the technical components and workings of biofuels.

Chapters 2 to 5 cover the first case study: the Dutch biofuel development trajectory, 1990-2010. The development trajectory is divided into three time periods presented in separate chapters. Each period is told and analysed first from an SNM perspective and then from a discourse perspective. The Dutch case study displays a generally slow biofuel development and implementation trajectory, despite the existence of advanced biofuel R&D since the 1980s and of small-scale trials with conventional biofuels in vehicles and boats from the early 1990s. This is partly because the Dutch government prioritized highly technically advanced biofuels, which due to their immature state were not easy to implement. In the 2000s, conventional biofuel implementation increased rapidly aided by various policy incentives. The result was a small biofuel vehicle market dominated by ethanol in the latter years and a large market for low blends in fossil fuel vehicles. The SNM analysis of the Dutch case shows that limited protection, in terms of government incentives, set the pace and type of biofuel implementation. The discourse analysis shows that government protection would not have come about at all had it not been for persistent lobbying activity by biofuel coalition actors, and events such as the agricultural crisis in the 1990s, tougher CO_2 reduction targets and political pressure from the EU.

Chapters 6 to 8 cover the second case study: the Swedish biofuel development trajectory, 1970-2010. The Swedish case is divided into two time periods and, like the Dutch case study, told and analysed from both an SNM and a discourse perspective. In general, the Swedish case shows continuous biofuel experimentation and implementation with strong support from the government for both conventional and advanced biofuels. When experiments began in the 1970s they focused on advanced methanol R&D and fossil methanol field trials. In the mid-1980s, there was a shift from methanol to ethanol, both conventional and advanced technology processes. An ethanol focus was established which remained until 2010. Ethanol was implemented in buses in the 1980s, and a market for ethanol buses was developed in the 1990s which later expanded to personal vehicles as well as high and low blends in fossil fuels. Additional biofuels entered the market at the end of the 1990s – biogas and low-blend biodiesel. However, biodiesel gained less support compared to other biofuel alternatives at this time, which hampered its expansion. Biofuel market expansion continued in the 2000s with ethanol and biodiesel in the lead because of their expansion into low-blend markets. In addition, the 2000s saw increased interest in other advanced biofuel fuels in addition to advanced ethanol. The Swedish SNM analysis shows that positive niche development went hand in hand with protection in terms of financial incentives from public authorities, on the one hand, and positive network formation, expectations and learning processes, on the other. The discourse analysis indicates that the type and degree of government incentives over time were dependent on a variety of factors, such as the types of actors, their beliefs, interests and interactions.

In the conclusions (chapter 9), the two case studies are compared in order to answer the research question on the differences in biofuel development trajectories. The chapter closes with a reflection on the theoretical consequences of this work. The SNM analysis presents three key conclusions about the larger degree of biofuel implementation in Sweden. First, the Swedish case shows a greater amount of and higher quality of learning. Second, the Swedish biofuel networks are larger and more heterogeneous with more collaborative and better aligned activities compared to the Dutch. Third, the Swedish case displays more positive and widespread expectations, which are fed by positive learning experiences, network developments and continual policy protection. The discourse analysis of the policy process contributes five additional explanations for the different development trajectories. First, while both countries have been given continual protection to advanced biofuels, earlier and larger scale market implementation in Sweden are related to its much greater and almost continuous protection of conventional biofuels. Second, a different type of policy support for conventional biofuels resulted in a different type of biofuel implementation. The Netherlands prioritized regulatory measures while Sweden prioritized subsidies, which stimulated the development of biofuel vehicle fleets in Sweden to a larger degree than the Netherlands. Third, biofuel development is influenced by the types of discourse in the national context. The Dutch prioritization of advanced biofuel solutions indicates a supply-driven approach in search of the optimal technology solution – a technological fix. In Sweden, on the other hand, the discourse analysis indicates an approach driven by both supply and demand, due to higher public pressure to reduce problems in the transport sector by means of biofuels, which has allowed for greater biofuel implementation. Fourth, the greater promotion of conventional biofuels in Sweden has also contributed to a wider institutionalization of conventional biofuel use through the establishment of a large biofuel vehicle market. That the Dutch focused their conventional biofuel support on low blends which are relatively more easy to replace reflects an ambition to avoid the institutionalization of these fuels. Fifth, the Swedish case shows a more successful and smoother discourse development pattern than the Dutch. Dutch biofuel discourse development has displayed a great deal of rivalry. The smooth discourse development in Sweden can be traced to the national context – the values and interests of actors that have been more eager to become independent of fossil fuels, and to make use of Sweden's vast natural resources compared to those of the Netherlands.

The main theoretical conclusion is that an SNM analysis is not sufficient to explain the difference in Swedish and Dutch biofuel niche development, since it cannot explain why some biofuels were protected while others were not. This thesis contributes to the transitions literature by setting the basis for a new framework – a combined framework of SNM and discourse theory that demonstrates the complexity of policy dynamics, which SNM and other transition perspectives choose not to explain. By revealing the dynamics of the policy process, discourse analysis contributes not only to transition analytical perspectives, but also to the development of more suitable policy instruments to steer transitions in a desired direction. The thesis ends with a theoretical discussion on how best to integrate the two theoretical perspectives into a combined framework.

About the author

Johanna Ulmanen was born on 10 August 1976 in Huddinge, Sweden. She has an interdisciplinary research background with a particular interest in the field of "transition studies", which focuses on processes of change to a more sustainable society. She studied various social sciences at universities in Sweden (Umeå, Uppsala and Stockholm), Ireland (Trinity College, Dublin) and the Netherlands (Maastricht). She graduated with distinction from Maastricht University in 2001 and holds a Master of Arts in science, technology and society (STS) studies. In late 2003 she started a PhD project at the School of Innovation Sciences at Eindhoven University of Technology in the Netherlands, the results of which are presented in this thesis. The research results have been communicated through teaching at Eindhoven University of Technology, presentations at international conferences (such as the 15th European Biomass Conference and Exhibition and the 4S/EASST Conference) and at the Dutch Ministry of Housing, Spatial Planning and the Environment. The PhD project also engaged her with research schools such as the Netherlands Graduate Research School of Science, Technology and Modern Culture (WTMC) and the Knowledge Network for System Innovations and Transitions (KSI), of which she is still a member. She is also a member of the Sustainability Transitions Research Network (STRN). Before her PhD project she worked as a research assistant at the department of Arts and Culture at Maastricht University (2001-2003) on both tutoring and research tasks. In parallel with her PhD project, she worked in Sweden as a Research Associate with the Stockholm Environment Institute (SEI) in 2009-2011 and at Lund University (2013). In these positions she worked closely with the Mistra-SWECIA research programme, completing a historical analysis of the debate on the potential future impacts of climate change on the Swedish forestry sector.