

## MASTER

### Sustainability transitions from a road mobility perspective set up recommendations for a large-scale biofuel value-chain near Rotterdam

van der Beesen, P.H.R.

*Award date:*  
2007

[Link to publication](#)

#### **Disclaimer**

This document contains a student thesis (bachelor's or master's), as authored by a student at Eindhoven University of Technology. Student theses are made available in the TU/e repository upon obtaining the required degree. The grade received is not published on the document as presented in the repository. The required complexity or quality of research of student theses may vary by program, and the required minimum study period may vary in duration.

#### **General rights**

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain

Delft, August 2007

**Sustainability transitions from a  
road mobility perspective: Set up  
recommendations for a large-scale  
biofuel value-chain near Rotterdam**

by  
Philippe H.R. van der Beesen

B.Eng Mechanical Engineering — HsZuyd 2003  
Student identity number 0558505

in partial fulfilment of the requirements for the degree of

**Master of Science  
in Innovation Management**

Supervisors:

Dr. ing. G.P.A. Mom, Eindhoven University of Technology, General Sciences

Mr. ir. ing. I.P. Biemond, Eindhoven University of Technology, Technology & Policy

Ir. A.L. Schelling, TNO Built Environment and Geosciences, Mobility & Logistics

TUE. Department Technology Management.  
Series Master Theses Innovation Management, nr.5

ARW 2007 IMA / 5

Subject headings: transitions, sustainable development, liquid fuels, biomass, regional mobility

For questions or for more information: [philippevanderbeesen@hotmail.com](mailto:philippevanderbeesen@hotmail.com)

## Preface

The study in this report concerns a master thesis project, and completes the Innovation Management course, which I followed at the Technology Management faculty of the Eindhoven University of Technology. The five months study is commissioned by TNO's business unit Mobility & Logistics, and the department of Public Works of the city of Rotterdam. The research findings presented throughout the report form ingredients within a broader study about liquid biofuels for road transportation purposes, and its socio-economic impacts. That study in turn, is currently carried out in favor of the EU-supported 6<sup>th</sup> Framework Program: "BioEthanol for Sustainable Transport" (BEST). Briefly, the BEST project aims for an accelerated development of liquid biofuels and their applications, and involves demonstration and validation projects at more than ten strategically chosen regions across Europe. Both, TNO and the department of Public Works of Rotterdam participate in the BEST project. More information about the project can be found at <http://www.best-europe.org>.

Already in 2005, at the start of the master course, I decided to graduate in the field of sustainable development within the automotive sector, a topic for which I have been fascinated for a long time. For obvious reasons, I am very grateful for the research possibility offered by TNO Mobility & Logistics that fully complied with my aspiration and expectations. Essentially, the report provides a framework with preliminary set up recommendations for the creation and development of a large-scale biofuel value-chain (or industry) at the Port of Rotterdam. Although the potential gains of such chain are substantial, not merely in terms of economics, but, more valuably, on a global ecological dimension, they are not (yet) exploited sufficiently these days. The overall intention of the report is to focus on crucial parts related to this challenge, by building upon an extensive literature review covering multiple scientific disciplines. More than ever, I currently realize that any transition process towards sustainable systems entails ongoing multifarious and complex societal challenges. In such contexts, a collaborative approach on different levels appears to be the most efficient, also from a road mobility perspective. Accordingly, I hope this report is considered once more by involved stakeholders, in a sense that it provides backing for actions directed towards (biofuel) transition processes within the road mobility system, or as point of departure for further in-depth research.

Furthermore, I am thankful to all who supported me throughout this master thesis process. In particular I would like to thank the members of my graduation committee Gijs Mom, Ab Schelling, and Ies Biemond for reading and commenting on concept versions of this report. Moreover, I appreciate the freedom they gave me in defining and organizing the research project. Although this obliged a continuous critical reflection, in the end it improved substantially the overall personal learning effects in carrying out scientific research. Last but not least, I would like to thank Claire Goessens, my family, and my friends for their ongoing support and interest in what I am doing.

I honestly hope you will enjoy reading the report, as much as I enjoyed working on it.

Philippe van der Beesen

Delft, August 2007.

Some historical quotations which, imaginatively, demystify the report's context...

*“The significant problems we face cannot be solved at the same level of thinking we were at when we created them”*

*“Sometimes one pays most for the things one gets for nothing”*

*“The only reason for time is so that everything doesn't happen at once”*

...all by Albert Einstein (1879-1955).

## **Summary**

More than ever, humanity relies on a well-functioning global road mobility system. Ideally, such system fulfills its principal function in a sustainable manner. However, such system does not exist these days. Mounting evidence confirms that the world's present road mobility system operates unsustainable, and even in an ecological destructing manner. Calculations estimate that transport in the developed regions is responsible for 21% to 26% of all anthropogenic greenhouse gas emissions (GHGs). Future viability of mobility is only then secured when the system's risks, uncertainties and critical elements (e.g., resource availability), and adverse effects (e.g., health hazards, climate change due to growing GHGs) are addressed effectively, while preserving the characteristics that make mobility so desirable. Fortunately, courses being altered these days. Stakeholders from the complete value-chain and from every part of society throughout the world are increasingly engaged, and act in conjunction to realize transition processes towards a more sustainable global mobility system. Eventually, this desired system will embed efficient transport means and services, as well as a mixture of innovative (technological) solutions. However, the distant long-term shift is not likely to be a smooth one and requires overcoming intertwined technological, socio-economic, market, and institutional barriers, as well as clear (international) governmental leadership. The key impeding factors in the challenge towards a sustainable road mobility system are rather non-technical and dynamic (thus uncertain) in nature. Moreover, they involve complex cross-sector and cross-border matters.

The afore-mentioned developments in the road mobility system and its related challenges can be approached in relation to the scientific discipline of transition theory; a theory which conceptualizes similar long-term change processes in technology and society. Based on historical case-studies the theory is refined, and emphasizes the perspective that transitions are not driven by single factors or drivers, but come about through alignments of processes at different levels, i.e., the macro- (landscape), meso- (regime), and micro-level (niche). From a road mobility perspective, the macro-level pressures are currently reflected by several long-term trends around the topics of (1) quality of life (e.g., increasing environmental awareness, climate change concerns, the concept of sustainable development), (2) resource concerns (e.g., availability and price questions, dependency on political unstable regions), and (3) population/prosperity (e.g., globalization, rising prosperity in developing regions). Together these interacting mechanisms provide sufficient momentum to initiate, and indeed stimulate, transition processes towards more sustainable practices related to road mobility. Initially, these processes become visible through tangible innovative elements on the micro-level. Examples are the market introduction (and significant success) of hybrid propelled vehicles, international pilot and demonstration projects around alternative fuels, and novel policy measures (e.g., tax privileges related to energy efficiency). Ultimately, the innovations' niche functions may 'leak out', and penetrate into the meso-level, where new, stable regimes are formed (e.g., a biofuel-based refueling infrastructure). More explicitly, this process is supported by the hybridization and niche accumulation strategy that principally facilitate a straightforward market introduction of new technologies. Briefly, hybridization refers to an introduction of the innovation in mainstream markets (e.g., as add-on element), so that it

can integrate more easily and benefit from existing infrastructures. Conversely, niche accumulation underpins an introduction in multiple, fundamentally different market niches that radically differ from existing practices. In most cases, a balance between both strategies appears best for a smooth, large-scale market breakthrough for any innovation, also for environmentally benign road transportation technologies (e.g., biofuels). Above all, transition theory encloses a societal meaning too, in a sense that it forms the basis for the Dutch policy approach to induce (energy) transitions aimed at sustainability; it basically guides policy makers in their coordination and steering efforts. In sum, the discipline of transition theory may symbolize the train of thoughts when it comes down to managing transition pathways in practice more effectively, also when sustainable mobility is the aim.

One of such transition pathway involves large-scale adoption and diffusion of biofuels like ethanol and biodiesel. Already from 1900 onwards, biofuel production has had many peaks and valleys since it responds to complex combinations of changes in demand, economical and political interests. To date, biofuels experiencing again unprecedented levels of attention due to its value as alternative to dominant petroleum fuels. Actually, no significant reasons are found to be skeptical about biofuels' potential ability to (1) be exploited viably on a worldwide-scale in the medium- to long-term, and capture at least 30% of today's petroleum fuels' market share, (2) stimulate socio-economic development in developing and rural regions, (3) reduce the local and global environmental burden stemming from the road mobility system, (4) better secure and diversify energy supply, and (5) lessen dependency on political unstable regions. These beneficial characteristics are general motivations convincing governments over the world to perceive liquid biofuels as highly relevant, within the transition towards a sustainable mobility. However, a rapid shift towards a bioenergy-based economy requires addressing significant issues. Besides improving its economic outlook, the prospective competition with food crops must be managed rightly, in a world where famine prevails in more than a few regions. Furthermore, an international agreed biomass certification system must ensure minimum social and ecological standards, and biofuel quality standards in turn are required to facilitate (competition-based) international trade. These days, solutions to biofuels' critical issues are explored, but come across in various stages. In essence, this explains the rather slow progress in turning biofuels into a global-scoped commodity.

Also in the Netherlands, the expected increase in biofuel demand sets the attention by governmental bodies, industries, entrepreneurs, and NGOs. Although the country lacks a tradition in producing or using large amounts of biofuel, and suffers from an uncertain investment climate around bioenergy due to frequent changing economic incentives and policy measures, the current 2007 legislative framework (obliging an increasing percentage of biofuels share in petroleum-derived road transportation fuels over the next three years), provides a relative clear and stable outlook. In this context, the Port of Rotterdam possesses a unique set of characteristics from which biofuel-related activities can benefit substantially. The set up of a large-scale biofuel value-chain is defensible at that site since it shapes a huge socio-economic and strategic potential. Moreover, it assists in the challenges towards a sustainable road mobility system. For obvious reasons, transition theory combined with insights from recent past experiences around biofuels, provides valuable preliminary recommendations with regard to the operational organization and business policy of the biofuel value-

chain. Especially the chain's vertical and horizontal integration, and the exploitation of scale effects, are key critical factors that will improve the chain's overall viability. Instead of perceiving oil industries as competitor, they should be 'embraced' as valuable collaborative partners. Furthermore, the chain has to be linked with multiple sectors (e.g., agro-food industry, chemical sector) by means of their core- and co-products, on operations- and R&D-level. By applying this business strategy, the theoretical thoughts of hybridization and niche accumulation can be translated into a practical accomplishment.

Nonetheless, biofuels are no 'holy-grail solution' in road mobility and will be combined with other building blocks including among others more efficient motor vehicles, attractive mass-public transportation means, and alternative fuel and propulsion concepts. Together these will help the world achieve a more diversified and sustainable transportation system in the decades ahead. In the end, the transition will shape both the nature of the fuel and vehicle industry, a process which remains highly speculative for now.





# Table of contents

<b>Preface .....</b>	<b>3</b>
<b>Summary .....</b>	<b>5</b>
<b>Table of contents .....</b>	<b>9</b>
<b>Table of figures, tables, and boxes .....</b>	<b>13</b>
<b>1 Project context and research methodology .....</b>	<b>15</b>
1.1 Research context.....	15
1.1.1 Introduction .....	15
1.1.2 Research area exploration.....	15
1.1.3 Initial problem identification .....	16
1.1.4 Research environment at TNO in favor of the BEST project .....	16
TNO Mobility & Logistics .....	16
BEST project.....	17
1.1.5 Research motivation .....	17
1.2 Objectives .....	18
1.2.1 TNO M&L.....	18
1.2.2 BEST project.....	18
1.3 Problem demarcation and methodology.....	19
1.3.1 Research questions part A .....	19
Background .....	19
Question 1 .....	20
Question 2A .....	20
Question 2B.....	21
Question 3 .....	21
Research strategy.....	22
1.3.2 Research questions part B.....	23
Background .....	23
Question 4 .....	24
Question 5 .....	26
Research strategy.....	26
1.3.3 Overall research objective and framework .....	27
1.4 Report's planning and added value .....	27
1.4.1 Planning and outline.....	27
1.4.2 Added value.....	28
<b>2 Part A: About sustainable road mobility .....</b>	<b>29</b>
2.1 Introduction .....	29
2.1.1 Aims and structure of this chapter .....	29
2.1.2 Method of approach.....	29
2.2 The mobility dilemma.....	29
2.2.1 Mobility is desired.....	29
The golden age .....	30
Economic growth .....	30
2.2.2 Concerning trends: impacts and threats .....	30
Resource availability .....	31

Environment.....	31
Local effects.....	32
2.2.3    The quandary.....	32
2.3    Challenges.....	33
2.3.1    Indicators and goals.....	33
2.3.2    Act in conjunction.....	34
Novelties and building blocks.....	35
Political institutions.....	35
Industry and other NGOs.....	37
Society.....	39
2.3.3    Obstacles of structural nature.....	39
Chicken-and-egg dilemma.....	39
Prisoners' dilemma.....	40
2.4    Discussion of research question 1.....	40
2.4.1    Introduction.....	40
2.4.2    Elaboration Q1.....	41
2.4.3    Concluding words.....	42
<b>3    Barriers for novel building blocks.....</b>	<b>43</b>
3.1    Introduction.....	43
3.1.1    Aims and structure of this chapter.....	43
3.1.2    Method of approach.....	43
3.2    Discussion of research question 2A.....	43
3.2.1    Introduction.....	43
3.2.2    Elaboration Q2A.....	44
Technological hurdles.....	44
Supply, distribution infrastructures and maintenance networks.....	44
Competency issues.....	45
Political institutions and regulatory frameworks.....	46
Market demand.....	46
Cultural and public perception.....	48
Objectionable societal and environmental effects.....	48
3.2.3    Concluding words.....	48
3.3    Discussion of research question 2B.....	50
3.3.1    Introduction.....	50
3.3.2    Elaboration Q2B.....	50
Technological hurdles.....	50
Supply, distribution infrastructures and maintenance networks.....	51
Competency issues.....	52
Political institutions and regulatory frameworks.....	52
Market demand.....	52
Cultural and public perception.....	53
Objectionable societal and environmental effects.....	53
3.3.3    Concluding words.....	53
<b>4    Transitions towards sustainability.....</b>	<b>55</b>
4.1    Introduction.....	55
4.1.1    Aims and structure of this chapter.....	55
4.1.2    Method of approach.....	55
4.2    Understanding transitions.....	55
4.2.1    An introductory.....	55
Evolution theories and technological change.....	57

Innovation forms and regimes of stability .....	58
Co-evolution and inter-artifactual competition.....	59
4.2.2 Transition characteristics.....	59
4.3 Inducing sustainability transitions in practice.....	60
4.3.1 Transition management .....	60
Arenas .....	61
Agenda .....	62
Experiments and learning.....	62
4.3.2 Transition management: the itinerary towards sustainable road mobility?.....	62
4.3.3 Transition strategies: towards sustainable road mobility.....	63
Niche accumulation.....	64
Hybridization.....	64
Choosing between the two strategies.....	65
4.4 Discussion of research question 3.....	66
4.4.1 Introduction .....	66
4.4.2 Elaboration Q3 .....	66
4.4.3 Concluding words.....	67
<b>5 Part B: Biofuels and the value-chain .....</b>	<b>69</b>
5.1 Introduction .....	69
5.1.1 Aims and structure of this chapter .....	69
5.1.2 Method of approach.....	69
5.2 Discussion of research question 4.....	69
5.2.1 Introduction .....	69
5.2.2 Elaboration Q4: Lessons about .....	70
Biofuels' technological outlook .....	70
Political commitment to biofuels.....	71
International collaboration .....	71
Consistent economic support mechanism.....	72
5.2.3 Concluding words.....	73
5.3 Discussion of research question 5.....	73
5.3.1 Introduction .....	73
5.3.2 Elaboration Q5: Biofuels' market prospective.....	74
Global-scale analysis.....	74
National analysis .....	75
Regional analysis.....	78
5.3.3 Concluding words.....	80
<b>6 Discussion and conclusions.....</b>	<b>83</b>
6.1 The framework with recommendations .....	83
6.1.1 Introduction .....	83
6.1.2 Contextual recommendations .....	83
International collaboration .....	83
Biomass certification system.....	83
Common biofuel quality standards.....	84
Political commitment .....	84
6.1.3 Rotterdam biofuel value-chain specific recommendations .....	84
Chain integration .....	84
Scale effects .....	85
Competition.....	85
6.1.4 The framework .....	86
6.2 Conclusions and directions for further research.....	87

<b>References.....</b>	<b>89</b>
<b>7 Appendix A: The biofuels case-study .....</b>	<b>95</b>
7.1 Introduction .....	95
7.2 What are biofuels? .....	96
7.2.1 Biodiesel, feedstocks and process technology .....	96
Feedstock and production process technology .....	96
7.2.2 Ethanol, feedstocks and process technologies .....	97
Feedstock and process technologies .....	97
Sugar cane-to-ethanol.....	98
Grain-to-ethanol .....	98
Lignocellulosic biomass-to-ethanol.....	99
7.2.3 The challenge .....	100
7.3 Historical perspectives.....	100
7.3.1 1900-1972.....	100
Vegetable oils and biodiesel.....	100
Ethanol .....	101
7.3.2 1973-today.....	103
Biodiesel.....	103
Brazilian ethanol .....	104
US ethanol.....	105
7.4 Biofuels global potential: benefits and critical issues .....	106
7.4.1 Introduction .....	106
7.4.2 Benefits .....	108
Reductions in oil demand .....	108
Reduction in GHGs, local pollution, and waste.....	109
Waste reduction.....	109
Vehicle performance benefits.....	110
Agricultural and employment opportunities.....	110
7.4.3 Critical issues .....	111
Price .....	111
Competition.....	112
Trade schemes.....	112
Biofuel quality standards.....	113
Biomass sustainability criteria and certification .....	114
7.5 Closing remarks.....	115
<b>Appendix B: Possible pathways of advanced transport (bio)fuels.....</b>	<b>117</b>
<b>Appendix C: Long-term oil price trend .....</b>	<b>118</b>
<b>Appendix D: Front-end modalities in the biofuel supply chain (schematic) .....</b>	<b>119</b>
<b>Appendix E: Ethanol’s (potential) production and plans for use per region .....</b>	<b>120</b>
<b>Appendix F: Biomass certification: criteria and indicators .....</b>	<b>121</b>

## Table of figures, tables, and boxes

<b>Figure 1:</b> S-curve of technical introductions and the 3 stages (Sixth Framework Programme 2005)	17
<b>Figure 2:</b> Three levels of transitions (source of design: Kemp & van den Bosch 2005: p.7)	20
<b>Figure 3:</b> Schematic research strategy part A	22
<b>Figure 4:</b> Schematic research strategy part B	26
<b>Figure 5:</b> Overall research framework	27
<b>Figure 6:</b> Projection world primary energy demand (WEO 2005)	31
<b>Figure 7:</b> Share of worldwide CO <sub>2</sub> emissions from fuel combustion per sector (EIA/DOE 2000)	32
<b>Figure 8:</b> Sulfur trends in gasoline and diesel in different countries/regions (IFQC 2002)	38
<b>Figure 9:</b> Conceptualization of current macro- and micro-level pressures that create momentum and stimulate the sustainable road mobility transition on the meso-level	42
<b>Figure 10:</b> Population of road horses and number of cars in US (Nakicenovic 1986: p.320 from Geels 2002: p.39)	56
<b>Figure 11:</b> The cycle of transition management (source of design: Rotmans 2005 p.53)	61
<b>Figure 12:</b> Existing trade routes according to IEA/T40 (2006) and the theoretical bioenergy potential in 2050 per region and for the world according to four scenarios in Smeets, Faaij & Lewandowski (2004) (Source of world map: <a href="http://chuma.cas.usf.edu/~juster/volc1/world%20map.gif">http://chuma.cas.usf.edu/~juster/volc1/world%20map.gif</a> )	74
<b>Figure 13:</b> Geographic overview of all projects involved with the production, import & distribution, and use of biofuels (ethanol, biodiesel, ppo, biogas) active in 2006 (the inventory is based on data from table 9 and linked with the location of each project/initiative in the Netherlands)	78
<b>Figure 14:</b> Supply chain and projected main production-related activities in the Rotterdam biofuel value-chain (activities for biodiesel and ethanol production, based on the case-study)	79
<b>Figure 15:</b> Geographic overview of the companies presented in table 10 at the Port of Rotterdam (Port map edited from: <a href="http://www.portofrotterdam.com/nl/feiten_cijfers/havenkaarten/branches/index.jsp">http://www.portofrotterdam.com/nl/feiten_cijfers/havenkaarten/branches/index.jsp</a> )	80
<b>Figure 16:</b> Operations-related integration opportunities (horizontal and vertical) of Rotterdam biofuel value-chain for core- and co-products, according to the hybridization and niche accumulation market introduction strategies	81
<b>Figure 17:</b> Ethanol production steps by feedstock type and conversion technique (source of text: IEA/OECD 2004)	98
<b>Figure 18:</b> Worldwide and regional production of ethanol fuel (left, 1975-2003), and biodiesel (right, 1991-2003) (F.O. Lichts 2004 from IEA/OECD 2004 p.28 & 29)	107
<b>Figure 19:</b> Learning curve effect: long-term comparison ethanol prices in Brazil and regular gasoline prices in Rotterdam (UN/DESA 2005: p.14)	108
<b>Figure 20:</b> Range of estimated GHGs reduction from ethanol and biodiesel (IEA/OECD 2004: p.13)	109
<b>Figure 21:</b> Cost ranges for ethanol and biodiesel production in US dollars per gasoline/diesel-equivalent liter (IEA/OECD 2004: p.85 & 86)	111
<b>Table 1:</b> Indicators and goals for sustainable mobility (WBCSD 2004)	34
<b>Table 2:</b> Short-term strategies for EU legislative framework, cutting GHGs from cars (EC/IP/07/155 2007)	36
<b>Table 3:</b> Important interrelated factors impeding large-scale commercialization of sustainable road transportation technologies	49
<b>Table 4:</b> Important factors impeding large-scale commercialization of biofuels in the Netherlands	54
<b>Table 5:</b> Transition management as policy approach: guiding principles, rationale, steering, and preconditions for successful deployment (freely translated)	60
<b>Table 6:</b> Differences between niche accumulation and hybridization (Raven 2007: p.2392)	65
<b>Table 7:</b> Conceptual strategic directions for inducing sustainability transitions and suggestions for the framework with recommendations for the biofuel value-chain	67
<b>Table 8:</b> Overview of the scenarios and factors (Smeets, Faaij & Lewandowski 2004: p.41)	75
<b>Table 9:</b> Stakeholders involved in biofuel projects and initiatives in 2006 (source of data: <a href="http://gave.novem.nl/gave">http://gave.novem.nl/gave</a> )	77
<b>Table 10:</b> Biofuel value-chain's related markets at the Port of Rotterdam, and some examples of companies	80
<b>Table 11:</b> Biodiesel-diesel property comparison (IEA/OECD 2004)	110

**Table 12:** Themes and principles for sustainable production of biomass for energy, freely translated from TaskForce (2007: p.7 & p.10)

115

<b>Box 1:</b> Initial questions	16
<b>Box 2:</b> Transition-related research objective	18
<b>Box 3:</b> BEST-related objective	19
<b>Box 4:</b> Research question 1	20
<b>Box 5:</b> Research question 2A	21
<b>Box 6:</b> Research question 2B	21
<b>Box 7:</b> Research question 3	22
<b>Box 8:</b> Brief timeline sketch ethanol as fuel (based on the biofuels case-study in appendix A)	25
<b>Box 9:</b> Research question 4	26
<b>Box 10:</b> Research question 5	26
<b>Box 11:</b> Overall research objective	27
<b>Box 12:</b> The desirable benefits of mobility	30
<b>Box 13:</b> Statement about mobility	33
<b>Box 14:</b> Transition example: From horse-and-carriages to automobiles (1860-1930)	56
<b>Box 15:</b> Definition of a transition	57
<b>Box 16:</b> Definition of a socio-technical regime	58
<b>Box 17:</b> Conclusion about transition management with respect to sustainable road mobility	63

# 1 Project context and research methodology

## 1.1 Research context

### 1.1.1 Introduction

The selection of the research area originated from a combination of profound personal interests in both, future propulsion technologies for automotive applications and the concept of sustainable development in general. Although both individual themes might seem ‘hot’ topics and even hypes today, personally I have been fascinated by these for a long time, which, probably will turn to good account in favor of the report. This section introduces the research area, identifies two general acknowledged problems, sketches the environment in which the research project is carried out, and elaborates on the research motivation.

### 1.1.2 Research area exploration

Mobility is desired since it greatly facilitates human interactions, enables people and goods to overcome distance and makes economic growth all over the world possible (OICA 2002). Hence, society relies heavily on a well-functioning mobility system (Åkerman & Höjer 2006). On the other hand however, abundant scientific research confirms that the current mobility system substantially affects the environment in a negative way (e.g., WBCSD 2004). The growing seriousness of global energy problems and associated impacts on for instance the environment are increasing the importance of sustainable development, also in view of our mobility system.

From this perspective, the road transportation sector is high on many agendas. More than ever, governments, industries and research institutions across the world increasingly cooperate to identify problems, address challenges and find solutions that mitigate adverse effects resulting from transport-related activities. In brief, a broad coalition of stakeholders aims to achieve the transition<sup>1</sup> towards a sustainable road mobility system. However, despite the wide-ranging global commitment, concerning trends demonstrate an ongoing environmental deterioration, if actions to reduce or compensate transport-related adverse effects stay away or fail to succeed (Vergragt 2004).

One of the transition pathways to realize a more sustainable road mobility system involves large-scale adoption and diffusion of environmentally benign transportation technologies. The potential benefits of these technologies in transport are significant. Estimations show that the European Union (EU) could reduce its energy consumption by 20% by 2020, if today’s most advanced technologies are fully integrated in the market (EC/COM/265 2005). Largely discussed options that could power a significant proportion of the road transportation fleet over the next two to three decades include among others: advanced internal combustion engines, hybrid or full electric systems, fuel cell propulsion, and (in combination with) the use of alternative fuels like LPG, CNG, hydrogen and renewable liquid and gaseous fuels derived from biomass feedstocks (MacLean & Lave 2003).<sup>2</sup> Regardless of this ample set, and often proven options, there are many factors that impede the

---

<sup>1</sup> Freely defined, a transition refers to a long-term process of sweeping changes in an encompassing system (or regime) that serves a fundamental societal function (e.g., transportation, energy supply, communication, health care), and these changes alter the overall structure of such system drastically. The concept of transitions is further explained in sub-section 1.3.1 and chapter 4.

<sup>2</sup> Appendix B provides a more elaborated overview of potential combinations of alternative energy carriers and drivetrains.



development and use of new and more sustainable technologies for the road transportation sector (Kemp, Schot & Hoogma 1998). These circumstances introduce attention-grabbing questions and concerning global issues.

### **1.1.3 Initial problem identification**

The brief introduction of the research area identified some general, global problems with associated challenges. First of all, it appears that our indispensable road mobility system operates in an unsustainable manner and society is increasingly aware of that. To secure the system's future viability and mitigate its environmental impacts, transitions towards more sustainable practices are necessary. Regardless of the current wide-ranging devotion of relevant stakeholders and many (often proven) technological concepts, a variegated set of barriers have to be overcome to realize large-scale commercialization of environmentally benign technologies in the road transportation sector. These apparently relevant and problematic issues introduce the following initial questions:

- What stimulates the transition towards sustainable road mobility?
- By what means can the development and utilization of environmental benign technologies in the road transportation sector be encouraged?

#### **Box 1: Initial questions**

Unambiguously, these research questions are too broad to tackle at once in detail within the provided timeframe for the project in this report. Hence, it is required to divide up the research into smaller pieces and specify the research objectives for explicit purposes. This in-depth problem demarcation is explained in the next two sections. Prior to this, an elaboration of the environment in which the research project takes place and the motivation is given below.

### **1.1.4 Research environment at TNO in favor of the BEST project**

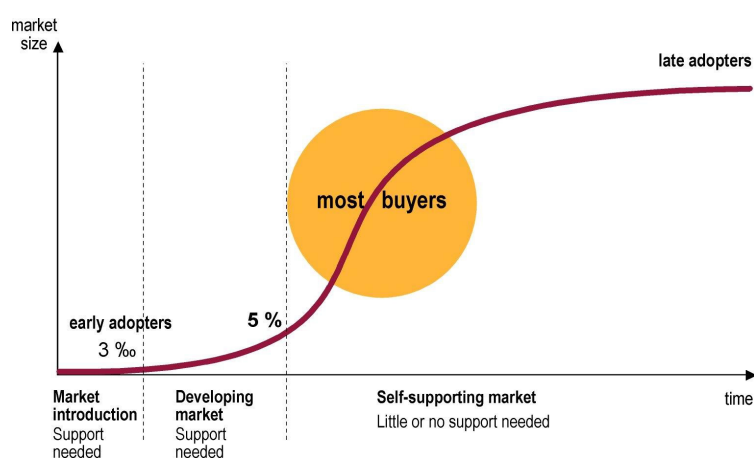
The research project is carried out at TNO in Delft in favor of both, the institution itself and the BEST project in which the city of Rotterdam (department of public works) and TNO currently participate. A brief introduction of TNO as research institution and the BEST project:

#### TNO Mobility & Logistics

The Netherlands Organization for Applied Scientific Research (TNO) is one of the largest research and technology organizations in Europe. The daily work of some 5,000 employees is to develop scientific knowledge and to make that knowledge applicable to strengthen the innovative capacity of businesses, organizations, and the government. The business unit Mobility & Logistics (M&L) is part of the research group TNO Built Environment and Geosciences. M&L conducts research and gives advice on passenger and freight transport, transport and infrastructure technologies and logistics. It has a multidisciplinary structure and draws on the experience of (transport) engineers, economists, mathematicians, urban planners and information scientists. M&L's main customers are central and regional governmental bodies as well as (non-)profit organizations.

## BEST project

To date, TNO M&L is involved in the BEST demonstration and validation project. This project, stimulated by the EU, aims to demonstrate the feasibility of an extensive substitution of common gasoline and diesel fuels by biofuels,<sup>3</sup> with ethanol and biodiesel in varying blending percentages in particular. The four years project attempts to initiate an accelerating and lasting development of these biofuels in Europe. To date, there is virtually no market at all in Europe. The intention is to reach a market share of 5% as soon as possible since prior introduction experiences with new technologies (e.g., microwaves, mobile phones) show a self-supporting market from 5% market share onwards. This is visualized in figure 1. Brazil is the undisputed frontrunner as far as biofuels (ethanol in particular) concerned. In that country a self-supporting market exists already since the early 1980s. Currently, developing markets are found in the United States and Sweden.



**Figure 1: S-curve of technical introductions and the 3 stages (Sixth Framework Programme 2005: p.6)**

Furthermore, the BEST project demonstrates prerequisites for market breakthrough of biofuel-fuelled vehicles which is currently done through a substantial, subsidized and sponsored, introduction of vehicles and fuel distribution locations at 10 strategically chosen regions, under which Rotterdam. Finally, the project entails public information campaigns, environmental impact studies, and studies on effects of different kinds of local, regional, and national incentives. The overall BEST project objective is to reduce GHGs and dependency on oil, by large-scale introduction of biofuels in Europe.

### **1.1.5 Research motivation**

The local governmental body of public works in Rotterdam contracted TNO to assist with the set up and evaluation of BEST-related activities carried out in forthcoming years in Rotterdam region. The research activities for TNO are broad and range from specific emission testing, providing advice, to overall process evaluation and reporting of final results. TNO's participation in this project is valuable for the BEST project and the institution itself, in that it facilitates the build up and application of scientific knowledge in the field of market introduction strategies for environmental benign fuels in

---

<sup>3</sup> Biofuels are produced from biomass feedstocks (i.e., organic material) through a number of chemical processes. The term commonly applies to liquid transport fuels, but also includes gaseous and solid fuels such as biogas, wood pellets and chips.

the (Dutch) road transportation sector. Indirectly, the project sheds light upon the concept of energy sustainability transitions, which could serve for the benefit of related future projects.

The research activities carried out in this report are in favor of both, TNO and the BEST project. For TNO M&L especially the theoretical-oriented elements of the research about dynamics in, and management of sustainability transitions (part A) are valuable and add up to the vast amount of transition-research already carried out by TNO (e.g., Tukker & Butter 2007). Partner public works of Rotterdam is particularly interested in the more practical outcome of this research project, i.e., preliminary recommendations for the creation and development of biofuel-related economic activities in Rotterdam region (part B). Subsequently, these recommendations combined with other biofuel-related studies form ingredients within the BEST project framework and a broader socio-economic study about biofuels. The next section discusses the research objectives and explains the rationale to break up the report into two parts with a focus on sustainability transitions in part A, and a (regional) focus on biofuels in part B.

## 1.2 Objectives

### 1.2.1 TNO M&L

Recently, the Dutch central government (one of TNO M&L's key customers) developed and implemented a transition policy approach to address two significant energy-related challenges, i.e., climate change and supply security (VROMraad 2004). Generally, this policy aims to facilitate and steer energy transitions towards more sustainable practices in the Netherlands. In total, six core areas are identified in which transitions are perceived necessary. One of them is the road mobility sector (SenterNovem 2007) which, at least partially, clarifies the particular interests by TNO M&L in sustainability transitions in the field of road mobility. Currently, theoretical-oriented questions circulate about how such transitions emerge and evolve, what their pace affects, and whether they in fact can be managed, and if so, how? With regard to these questions, the first objective of this report concerns about sustainability transitions in the road mobility system and reads:

To evaluate the concept of sustainability transitions from a road mobility perspective, by providing a theoretical understanding of (1) the emergence of these transitions, (2) the mechanisms that affect their pace, and (3) the manageability of these transitions.

#### **Box 2: Transition-related research objective**

### 1.2.2 BEST project

As explained in sub-section 1.1.2, a multifarious set of barriers stagnate large-scale market introduction of environmental benign road transportation technologies. From this perspective, protected pilot and demonstration experiments in real-life settings, effectively executed by governmental bodies and/or industries, are perceived as strategy to reduce barriers and stimulate the rate of adoption and diffusion of new technologies (Kemp & van den Bosch 2006). Such pilot projects aim to create a significant market (supply and demand), and awareness-raising under society. Evidently, the BEST project can be characterized as such experiment since it aims to accelerate the market introduction of biofuels (new technology) in Europe. Noticeably, large-scale biofuel

introduction calls for substantial changes in the complete value-chain of fuels, i.e., the infrastructural organization (e.g., production, distribution, supply), institutional frameworks, and (international) regulations. In order to gain knowledge about these topics, partner public works of Rotterdam is commissioned to carry out different studies about incentives structures for biofuels, and regional economic development and market opportunities attributable to the expected large-scale introduction of biofuels. This last research topic leads to the BEST-related objective and is agreed with the department of public works in Rotterdam:

To propose a framework that provides preliminary recommendations for the development of a large-scale biofuel value-chain in Rotterdam region.

### **Box 3: BEST-related objective**

Since the transition objective is to some extent related to the BEST project activities and may provide input for the realization of the BEST objective, it is decided to amalgamate both topics of interest in this report. The idea is to split up the research into two parts. As a result, part A discusses the more theoretical aspects about sustainability transitions in the road mobility system. Subsequently, the outcomes of this part provide input for the more specific and practically-oriented objective in part B in favor of the BEST project. By addressing both objectives, the research activities carried out in this report serve both, TNO M&L and public works of Rotterdam with ‘their’ biofuels pilot and demonstration project BEST. The next section elaborates on the research questions and the strategy to realize the objectives discussed before.

## **1.3 Problem demarcation and methodology**

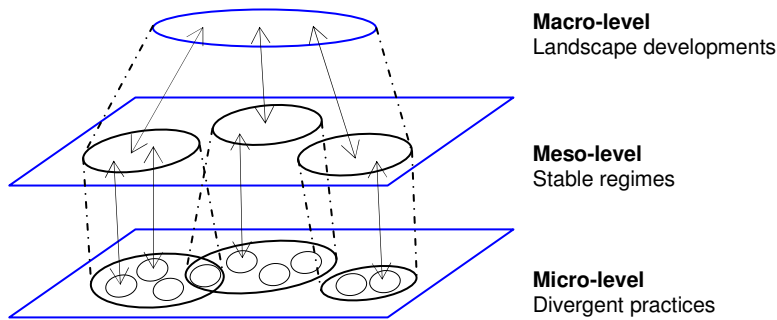
### ***1.3.1 Research questions part A***

By now, the research context is cleared out which resulted in two objectives. In order to realize both objectives effectively, it is necessary to unravel the objectives by defining specific research questions. By putting them in a well-constructed research framework, the strategy and steps to be undertaken to realize the objectives become visible. To identify relevant research questions for the transition-related objective, a preliminary literature review is performed about the state-of-art of transition theory.

#### Background

According to Rotmans et al. (2000), transitions are a result of affecting and intensifying developments in the field of economics, culture, technology, institutions and environment. In addition, transitions take place from time to time in every parts of society (e.g., healthcare, regional development, energy supply) (Drift 2006). Historical research pointed out that the dynamic developments that may cause a transition take place on different levels of the societal system, i.e., the macro-, meso- and micro-level (Kemp & van den Bosch 2006). Explained in a few words, transitions occur and become visible at the meso-level. This level consists of stable systems or regimes with dominant technologies and practices that serve a specific societal function, for instance the energy supply for households in the Netherlands. When established practices, actors or structures in such regime are in discordance with changing long-term trends and developments within the societal system on the macro-level, alteration pressures appear (Geels & Kemp 2000 from Kemp & van den Bosch 2006). In transition literature this

phenomenon is called the ‘urgency of change’. Following the household energy example, in the 1950s and 1960s, these pressures resulted in the transition from coal to natural gas as most important energy carrier in the Netherlands (Verbong 2000 from Rotmans 2005). Finally, on the micro-level, divergent (or abnormal) practices, often referred to as niche projects, take place in the field of economy, ecology, technology, culture etc. Ultimately, these actually visible and tangible practices might penetrate into the meso-level and consequently might facilitate and stimulate a transition process. Figure 2 conceptually visualizes the three levels of a transition and the interactions between them.



**Figure 2: Three levels of transitions (source of design: Kemp & van den Bosch 2005: p.7)**

### Question 1

Within this conceptual framework one might wonder what trends and specific developments on the macro-level and micro-level currently pressurize the global road transportation system (consisting of stable regimes), and create momentum for the transition process towards sustainable road mobility. This matter of fact introduces the first research question:

What mechanisms on macro- and micro-level currently pressurize, and thus stimulate, the transition towards a sustainable road mobility system?

### **Box 4: Research question 1**

### Question 2A

Of the various options to reduce the environmental burden, technology is commonly considered as most attractive. Furthermore, especially innovations are perceived as necessary to reduce the negative environmental impact (e.g., WBCSD 2001; Tukker & Butter 2007). Although to date many of these innovations are technically well-developed and even proven in reality, many kinds of factors impede the market introduction and large-scale utilization of new and more sustainable technologies for the road transportation sector. According to Reddy & Painuly (2004), such factors cover socio-economic, technological, market and institutional dimensions. For obvious reasons, one might state that the presence of these factors also stagnate the desired transition process. It is therefore valuable to identify and understand the factors at stake that form market penetration barriers for environmentally benign technologies for road transportation purposes.<sup>4</sup> This leads to the first part of the second research question:

---

<sup>4</sup> In this report, the term ‘barrier’ does not imply an absolute barrier, but is a metaphor for a constraining aspect that affects the implementation potential.

What type of factors form barriers for large-scale commercialization of sustainable road transportation technologies?

**Box 5: Research question 2A**

Question 2B

Considering this question, one might postulate that, as a consequence of these factors, the commercialization of biofuels in the Netherlands is hindered too. Anticipating on part B, focused on the biofuel sector, an understanding of how these factors shape introduction barriers specifically for biofuels is perceived as useful, and may provide input for part B. However, market potential for biofuels depends heavily on a plethora of circumstances in and around a country or region in which that market should prosper (Amigun, Sigamoney & Blottnitz 2006). It is therefore required to deduce these biofuel barriers from the general inventory of factors discussed in Q2A, and simultaneously take regional circumstances and the innovation context of biofuels into consideration. These thoughts lead to the second part of research question 2:

How do the factors discussed in Q2A shape barriers for large-scale commercialization of biofuels in the Netherlands?

**Box 6: Research question 2B**

Referring back to part A's objective, the first three research questions mainly elaborate on the emergence of transition in the road mobility system (Q1), factors that influence (impede) the pace of the sustainability transition process (Q2A) and the commercialization of biofuels in the Netherlands (Q2B). Although Q2B may not be directly linked with the transition objective of part A, the answer to this question provides input for the research in part B and is therefore discussed at this stage.

Question 3

By considering part A's objective and the previous research questions, an intriguing follow-up question arises and deals with the manageability of sustainability transitions in the road mobility domain, i.e., how to overcome the barriers such that promising environmentally benign technologies become successful products and the transition process is initiated? Literature is not unambiguous about this topic. This is explicitly underpinned by O'Riordan and Voisey (1998: p.xv) who argue that "there is no template for the transition to sustainability". In essence, Rotmans (2007) agrees with this statement by arguing that there is no clear recipe for a transition approach aimed at a more sustainable society. Nevertheless, he asserts that different paths can be indicated which fill up and strengthen each other in the pursuit to a sustainable society. Up till now one might conclude that each sustainability transition, though often with the same intentions, is unique in nature and requires a specific management structure.

From this point of view, the Dutch central government has recently adopted a transition management system as environmental policy tool that aims to induce sustainability transitions in different sectors. It is therefore questionable how that management system stimulates the desired transition towards sustainable road mobility, and what strategies are appropriate to address the

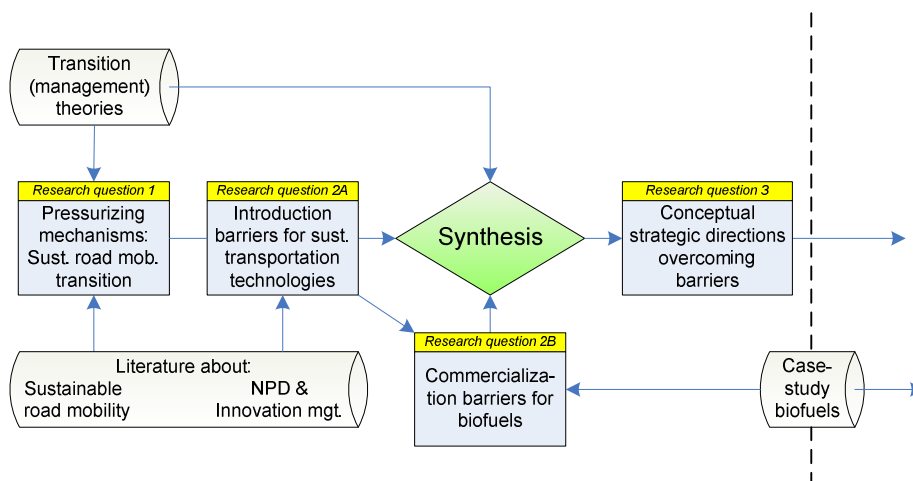
impeding factors and barriers discussed in research question 2A and 2B. Transition literature provides some guiding principles about these issues. However, given the fact that each (technological) sustainable alternative requires an individual market introduction strategy, also these questions should be answered by taking into account the state of affairs around biofuels. Accordingly, the answer (i.e., a discussion of the transition management system, and more specific strategic directions) is bipartite useful in that it contributes to the understanding of overcoming introduction barriers for sustainable road transportation technologies in general (for part A), and indirectly for the expansion of biofuel-related economic activities (for part B). This motivation shapes part A's final research question:

What conceptual strategic directions, from a transition theory point of view, lower barriers as discussed in Q2A and Q2B, and stimulate the desired transition process?

**Box 7: Research question 3**

Research strategy

The combined set of research questions discussed so far forms guidelines to the realization of the transition-related objective, which is partially in favor of the subsequent objective. The next step is to identify key bodies of knowledge that jointly form sources for the answers. After analyzing the first objective Q1, Q2A, and Q2B, it becomes clear that an understanding of sustainable road mobility (i.e., state-of-art, facts and figures, trends, etc.), transition theories, new product development, and an introduction to biofuels is indispensable. Subsequently, answering Q3 involves a synthesis process between the aforementioned acquired knowledge, and theories about transition management. Figure 3 visualizes the research strategy for part A. The cylinders represent bodies of knowledge, whereas the arrows indicate the flow direction of that knowledge. The vertical dotted line divides the research in part A (left side) and part B (right side).



**Figure 3: Schematic research strategy part A**

### **1.3.2 Research questions part B**

The previous sub-section elaborated on the theoretical part of the report. Below, a discussion is given about the research questions necessary to realize the more practical, biofuel-related objective. To refresh the memory the objective reads: “to propose a framework that provides preliminary recommendations for the development of a biofuel value-chain in Rotterdam region”. One might ask: why a biofuel value-chain in Rotterdam? The answer clarifies in a sense the objective’s rationale:

#### Background

Since the mid 1990s there has been a growing global interest in biofuels as road transportation fuel. This trend gathered pace in recent years, stimulated among others by increasing oil prices and the need to reduce GHGs (Rosillo-Calle & Walter 2006). Since biofuels enable opportunities for sustainable energy transitions, the utilization of biofuels is financially supported and stimulated by governmental bodies and international policies (e.g., the EU Biofuels Directive 2003/30/EG<sup>5</sup>). For instance, in France, Germany and Sweden the biofuel E85<sup>6</sup> is currently subsidized and end-user price, based on energy content, is comparable to that of gasoline. Hence, global demand for these fuels is expected to increase forthcoming years. Distribution country the Netherlands imports and exports already for decades substantial amounts of agricultural products and oil-based fuels through its well-developed harbors in Rotterdam with intercontinental connections. Not only conventional energy is an important segment for the Port of Rotterdam, these days the seaport already acts as key transfer point for biomass in Europe and accommodates four palm oil refineries. As a result of the expected global upturn of biofuels, a large economic potential arises for the import and processing of biomass and (international) export of biofuels. This may eventuate in a considerable added-value for the Dutch economy in this emerging sector (Gave 2003), and may even compensate to some extent the expected declining revenues on the long-term due to the exhaustion of natural gas fields. The central government of the Netherlands recognizes the potential of a biomass-related sector and aspires to create a ‘Bioport’, i.e., a large-sized biomass-processing environment (or valley) around Rotterdam, in which biofuels capture a significant share (SenterNovem 2007). The interests are also reflected by the industry given that, by the end of 2006, fourteen requests for the establishment of new biofuel-processing plants (ethanol and biodiesel) are submitted for that area (Ernst & Young 2006).

In sum, biomass, bioenergy, and biofuels are increasingly important for Rotterdam and neighboring regions. The investment climate for related activities seems very positive and the Port of Rotterdam may well develop into a global axis for biofuels worldwide. Furthermore, perceptible from this introduction both policy makers and industry partners have committed and strategic interests in the development of a biofuel value-chain in and around Rotterdam. The projected activities in that chain range from importing raw biomass feedstocks, processing into biofuels and exporting them to (inter)national destinations.

The objective’s rationale lies in the fact that the set up of such biofuel value-chain is surrounded by a multitude of potential (financial) risks for all stakeholders. Obviously, this is largely attributable to uncertainties about the amount of biofuels’ supply and demand, technological uncertainties, and other critical issues about biofuels as transportation fuel. However, as explained

---

<sup>5</sup> This directive demands from EU member states that a minimum proportion of biofuels is sold on their markets. Currently this is 2% on the basis of energy content of all transportation fuels sold in that market. By 2010 this amount will be 5.75%.

<sup>6</sup> Biofuel E85 is a volumetric mixture of 85% ethanol and 15% gasoline and can be used in flexible fuel vehicles.



before, the regional climate to date is attractive for various reasons. Additionally, competition from other international regions ambuscade, and first mover advantages may yield significant benefits for the expansion of biofuel-related activities in Rotterdam regions.

How to realize the objective? First, it must be emphasized that the framework will be preliminary in a sense that the recommendations are general in nature. One may think about advice about the biofuel value-chain's organization, the role of local and central governmental bodies, the short- and long-term growth-strategy, and suggestions about cooperation opportunities with other related industries and research institutions. Overall, the framework is intended for local policy-advisors in Rotterdam region, and provides strategic advice and guidance about the different involved biofuel value-chain's stakeholders. Second, one must take into account that the intention is to found the rather practically-oriented recommendations partially upon the theoretical research about sustainability transitions discussed in part A of the report. In a sense, this approach is novel and will, in all probability, contribute to an earlier acknowledged unfamiliarity in the field of transition theory, and exposed by Elzen & Wieczorek (2005: p.652): "the current research and up to date experience with transitions suggest that to be able to stimulate transitions towards sustainability we still need to build a strong knowledge base in this field." Furthermore, they point out two particular research challenges, namely (1) the need to improve insights about the dynamics of transition processes, and (2) the need to successfully apply these insights in the development of strategies and policies that induce and stimulate the occurrence of sustainability transitions. The theoretical research in part A combined with the practical implications provided in part B may make a contribution to this, which demystifies the added-value of the report. Finally, it is decided not to work out the framework in-depth because the report then could serve as starting point for further, more specific, research. Additionally, the provided timeframe for this project restricts a more detailed elaboration.

Given the information presented above, the realization of the objective will be based on a combination of part A's theoretical research findings, and an examination of biofuels as road transportation fuel, i.e., its historical developments worldwide, its critical issues, and the expected potential in the future in the short- and long-term. The final research questions, Q4 and Q5, explain why exactly this approach provides a foundation for realizing the objective and thus the framework with recommendations.

#### Question 4

Historical research reveals that fuels produced from organic feedstocks (i.e., biofuels) have already been applied as road transportation fuel in practically the first Otto engines available. An early example is the Ford Model T, produced from 1908-1927, which was designed as flexible fuel vehicle and could run on ethanol, gasoline, or a combination of both.<sup>7</sup> Several other vehicle types sold during the 1920s were offered with either gasoline or alcohol fuel systems since a dominant oil-infrastructure as it is known today did not exist at that time. Since then, the application of for instance ethanol as fuel or additive depends on a plethora of arguments on the political, financial and socio-economic dimensions. Additionally, geographical conditions are significant as well. This is briefly illustrated by the following timeline sketch about ethanol as road transportation fuel. In this case ethanol is depicted since this fuel is central within the BEST project.

---

<sup>7</sup> Interestingly, the 'ancient' flexible fuel technology as well as ethanol fuel are currently considered again as potential, more sustainable vehicle propulsion alternatives worldwide.

The main motivations to use ethanol in the early 20<sup>th</sup> century were (1) the octane increasing characteristic which allowed increasing engine compression ratios and inherently performance, and (2) the fact that domestically produced ethanol contributed to economic prosperity at national levels. Throughout the 1920s and 1930s, gasoline became the road transportation fuel of choice. However, Standard Oil (Esso) began adding ethanol to gasoline to increase octane and reduce engine knocking (EIA/DOE 2007). Just before mid-century, the increased fuel demand due to wartime significantly increased ethanol production. Once World War II ended virtually no commercial ethanol was available and the fuel was only used for niche applications (e.g., racing, agriculture). Several decades later, the 1973 OPEC oil embargo shocked oil-importing nations. Not only there was a dollar price to oil, there was a political price as well. OPEC showed that it could manipulate the dollar price, leaving importing nations vulnerable to large price increases and the economic havoc that they could cause (MacLean & Lave 2003). As a result, the US embarked on an ambitious plan to become energy self-sufficient which opened up new market opportunities for liquid fuels like ethanol and biodiesel. Also the Brazilian ethanol program started as a response to the Middle East oil embargo. At that time, Brazil's dependence on imported oil made it even more vulnerable than the US (Refocus 2006). As a result, the Brazilian government invested in a huge distribution network. Obviously, the favorable climate conditions, surplus of sugar cane fields, and low-cost labor certainly contributed to the success of ethanol in Brazil. To date, ethanol's environmentally benign characteristic (a beneficial function) and the possibility to blend in any ratio with gasoline (technical property) are seen as major drivers to employ the fuel at large-scale worldwide. Adding ethanol in small proportions to gasoline is still done these days by oil companies for different reasons.

**Box 8: Brief timeline sketch ethanol as fuel (based on the biofuels case-study in appendix A)**

From this historical point of view one might conclude that ethanol as product is trendy these days, yet ancient. Moreover, it is not competing with mainstream crude oil-based fuels but in actual fact, interacts and co-develops (due to the beloved functions and properties ethanol delivers) with the dominant oil technology, to become a more universal, multi-functional, and even better 'performing' fuel, i.e., a more sustainable road transportation fuel that reduces negative environmental emissions as well the dependency on relatively instable political nations. Mom (2003 & 2004) investigated conceptually similar interacting mechanisms between alternative technologies in several case-studies from a historical perspective. The interesting insights and conclusions revealed by Mom may be well-suited to provide more credible nearer-term strategic directions for biofuels which, for obvious reasons, then could serve in favor of the framework with recommendations. Furthermore, recent explorative laboratory research projects go even beyond the latest applications of biofuels and examine the opportunities to produce hydrogen from biomass feedstocks through gasification to use in fuel cells, a radical next-generation approach to fuel the future transportation sector (Ramesohl & Merten 2006). In this situation, biomass could provide a very low GHG source of hydrogen, even serving as a conduit for returning CO<sub>2</sub> from the atmosphere into the earth, if the hydrogen production process is combined with carbon sequestration (Read 2003). Also the identification of these longer-term opportunities and related challenges are better understood by taking into account the expected interacting mechanisms and the position biofuels take in those future developments. However, despite the seemingly many benefits, large-scale application of biofuels also raises questions about for instance food competition, biodiversity, socio-economic development, etc. These critical issues must be better understood before well-argued advice can be given. The notions presented above introduce research question 4:

What lessons can be learned from biofuels' past experiences, critical issues, and future prospects, in the interests of nearer-term strategic directions for large-scale application of biofuels?

**Box 9: Research question 4**

Question 5

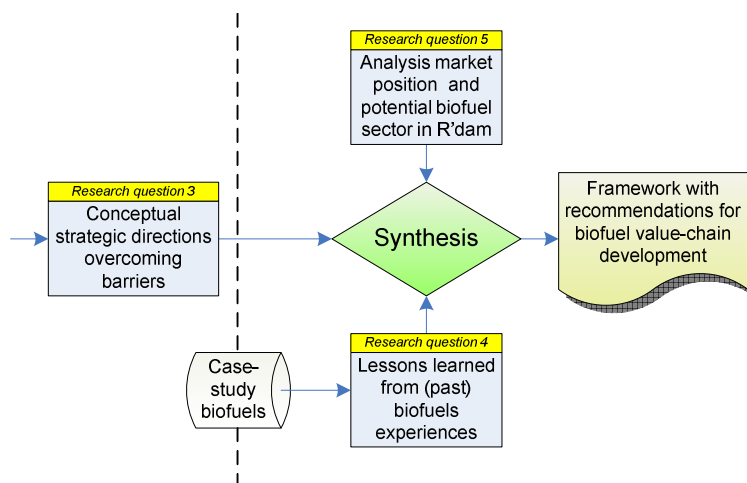
So far, local-bounded factors affecting the set up of the biofuels' value-chain have been neglected. The importance of these factors is reflected by the notion that technologists, economists and policy scientists are too familiar with the idea that even the best innovative technologies may fail if the necessary socio-economic and market conditions are not in place (Berkhout, Smith & Stirling 2003 from Hisschemöller, Bode & van de Kerkhof 2006). Obviously, these market conditions have to be present, not only on a global-scale, but also in and around Rotterdam, to successfully develop the biofuel value-chain. Earlier discussed factors (e.g., the Port of Rotterdam) and promising prospects (e.g., Bioport) already indicate a rather positive outlook for the desired chain in that region. However, a more thorough assessment of biofuels' global market position and the regional strengths is required to specify the framework for Rotterdam region. Consequently, the biofuel value-chain's market potential in that area is exposed in more detail. These considerations introduce the final research question:

What is biofuels' global market position, and what regional market conditions are in place around Rotterdam that could stimulate the set up of the biofuel value-chain?

**Box 10: Research question 5**

Research strategy

A direct synthesis process between Q3, Q4 and Q5 provides the necessary elements for the framework of recommendations for the biofuel value-chain development in Rotterdam region. A case-study about biofuels provides input for answering Q5. The strategy to realize the objective is visualized below.



**Figure 4: Schematic research strategy part B**

### 1.3.3 Overall research objective and framework

So far, both objectives are discussed in-depth. Additionally, the research strategies to realize the objectives are clarified by discussing research questions and constructing them into schemes. To conclude the section the overall research objective of the report is presented in box 11, followed by the merging of the individual schemes into the complete research framework of the report (fig. 5).

To provide advice for increasing biofuel-related economic activities in Rotterdam region, by presenting a framework with preliminary recommendations for the creation and development of a large-scale biofuel value-chain in that region. This framework is based on a combination of (1) a sustainability transition theory point of view, and (2) an assessment of biofuels' past experiences, critical issues, and expected market potential for the biofuel value-chain.

#### Box 11: Overall research objective

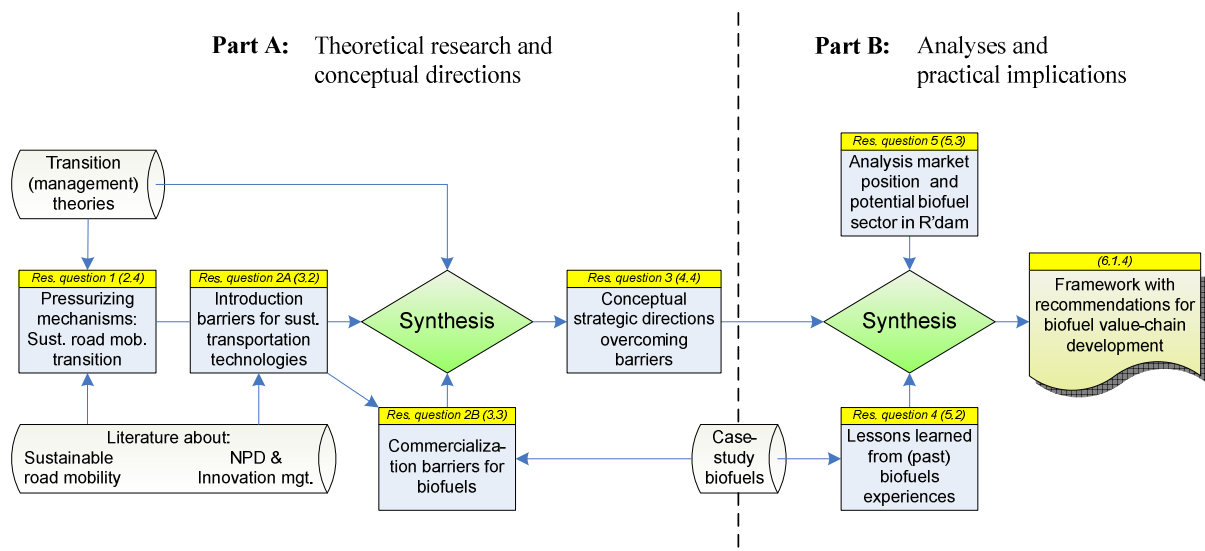


Figure 5: Overall research framework

## 1.4 Report's planning and added value

### 1.4.1 Planning and outline

The timeframe for the completion of the report, including the research proposal discussed in this chapter, is about five months and runs from mid-march 2007 to the end of august 2007. The research framework (fig. 5) is designed as step-by-step approach (from left to right) that ultimately results into the realization of the research project, the framework, and thus the completion of this report. The next chapter provides an introduction to the concept of sustainable road mobility. It sketches the global state-of-art concerning this theme, and addresses the first research question. Subsequently, chapter 3 discusses the factors that create barriers for environmentally benign road transportation technologies and biofuels, i.e., research question 2A and 2B. Chapter 4 elaborates on the theoretical backgrounds

about transitions towards sustainability, the transition management system, and two market introduction strategies for technological innovations. As a result, part A's remainder research question is addressed. The last core-chapter, chapter 5, elaborates on the lessons learned from prior biofuel experiences, and provides strategic directions aimed at a substantial market introduction of biofuels, i.e., research question 4. The case-study presented in appendix A about biofuels' past experiences, benefits and critical issues, and future prospects provides the basis for this question. Additionally, chapter 5 discusses the market analyses of biofuels on a global, national, and regional level, and the value-chain potential in Rotterdam region. Consequently, this chapter, combined with research findings from chapter 3 and 4 form the elements to construct the framework and ultimately deal with part B's objective. Finally, a discussion of the framework, the report's conclusions, and the directions for further research are given in chapter 6.

Each core-chapter commences with a more thorough elaboration of the aims, structure and method of approach, and is therefore not discussed at this stage. The workload distribution is projected as follows: the research proposal discussed in this chapter takes one month from project-start onwards. The remainder of the time is equally spread over the realization of both objectives, i.e., two months for the realization of part A and two months for part B.

#### **1.4.2 Added value**

The research's added value is threefold. First of all, it contributes to the knowledge building within TNO M&L about sustainability transitions from a road mobility perspective and the conceptual management of such transitions. This is done by synthesizing and summarizing existing, but diffused, literature. As a result this report may provide a theoretical basis for the sake of related projects in the future within the department. Secondly, the intention of the report is to arouse practical implications from the theoretical research carried out in the field of sustainability transitions. This is done by focusing on a specific technology (biofuels) in a region (Rotterdam) and providing advice that is partially based on the theoretical research about sustainable transition management, a historical retrospection about biofuels, their critical issues, and future potential. Combined with a global, national, and regional market analysis, a framework is constructed with preliminary recommendations for the creation of a large-scale biofuel value-chain near Rotterdam. Besides its specific value, the intention is to develop a framework which principally can be used in other situations too. Clearly, this adds scientific weight to the research. Finally, the report identifies directions for more in-depth research. Consequently, the report may serve as point of departure for subsequent research activities.

## **2 Part A: About sustainable road mobility**

### **2.1 Introduction**

#### ***2.1.1 Aims and structure of this chapter***

This chapter intends to provide general insights about the concept of sustainable mobility, its relevance, and the mechanisms that currently promote the transition towards a sustainable road mobility system.<sup>8</sup> Principally, this chapter provides the necessary background knowledge for answering research question 1. As a result, this question is discussed in the last section, and is founded on findings presented throughout this chapter.

In general, sustainable mobility is a multi-layered concept, involving a wide range of local and global aspects (e.g., economics, societal, environmental issues) across different areas (e.g., authorities, technology, citizens, modes of transportation) and within different time frames. Owing to its complexity, a detailed integrated approach, i.e., simultaneously taking all these dimensions into account, is virtually unfeasible and not an aim. Hence, it is required to limit the discussion and comprehend the concept of sustainable mobility in view of the report's specific purposes. That is, a focus on noteworthy environmental issues in the road mobility system.

The structure is as follows. First, the mobility dilemma is marked out by discussing global concerns about the environment and energy supply. In addition, facts and figures are presented regarding to environmental impact for which transportation is held responsible. Then, indicators of sustainable mobility and key stakeholders' contributions are discussed. Throughout the chapter, several plausible short- and long-term (technological) means are given that aim to address sustainability issues within the road transportation sector. The chapter ends with the discussion of research question 1, and a brief introduction towards chapter 3.

#### ***2.1.2 Method of approach***

Given the broadness of the sustainable mobility concept, an extensive literature review is performed that highlight the concept from different perspectives. A significant share of knowledge is derived from official regional and global reports, legislation, case studies and scientific papers in the field of (alternative) propulsion/fuels technology and sustainable development. This amount of knowledge is filtered and concisely summarized. Choices between breadth and depth of coverage are made with the intention to explain critical issues without overwhelming detail.

### **2.2 The mobility dilemma**

#### ***2.2.1 Mobility is desired***

“Mobility is principally a means of improving accessibility”, it greatly facilitates human interactions and enables people and goods to overcome distance (WBCSD 2001: p.1-5). Whether actualized

---

<sup>8</sup> This report complies with the definition of sustainable mobility proposed by the EU: “Sustainable mobility is a transport system and transport patterns that can provide the means and opportunities to meet economic, environmental, and social needs efficiently and equitably, while minimizing avoidable or unnecessary adverse impacts and their associated costs, over relevant space and time scales” (Atlantic 2001).

through walking, a horse, automobile, ship, or any other mode of (public) transportation, mobility is desired since humankind. Tokudo (1995) argues that people basically move ‘to survive’. Mobility stands for gaining access to life necessities and pleasure (Vergragt & Brown 2007). Hence, society is dependent on a well-functioning mobility system (Åkerman & Höjer 2006).

### The golden age

Innovations like the automobile at the end of the 19<sup>th</sup> century and the airplane at the beginning of the 20<sup>th</sup> century opened up opportunities for significantly increased speed and travel flexibility. As a result, the 20<sup>th</sup> century was a “golden age” of mobility (WBCSD 2001: p.1-1). The volume of personal travel and goods moved grew at unprecedented rates. This improved mobility has fundamentally contributed to the higher standard of living now enjoyed by the majority of the population in the developed world. According to calculations, comparable high grow rates of 3-4% annually are currently measured in developing regions like China, India and Latin America (SMP 2004). And indeed, one might state without exaggeration that the evolution of mobility that characterized the 20<sup>th</sup> century enabled the present growing globalized economy (e.g., Macharzina 1999; OICA 2002; Eldomiaty, Choi & Cheng 2007).

### Economic growth

In this context, transportation-related industries (e.g., logistic service providers, vehicle manufacturers, oil companies) are a significant contributor to economic growth. Not only the sectors themselves employ lots of individuals, especially the mere existence and availability of transport systems and services creates opportunities that otherwise would be unavailable. These opportunities include reliable, safe, secure, efficient, and affordable transport services, which in turn facilitate economic growth (WBCSD 2004). Especially in developing regions the transport sector currently acts as a magnet, inducing a positive economic spiral on a macro- and micro-level. As a result, these regions play a role in the ever increasing globalization and are able to participate in international trade (OICA 2002). In sum so far:

The desired benefits that come along with improved mobility cover socio-economic dimensions. Mobility connects people and things which is highly valuable itself and an essential prerequisite for modern (developing) economies worldwide. Furthermore, mobility is inherently linked with economic development, synergies exist and the one cannot go without the other.

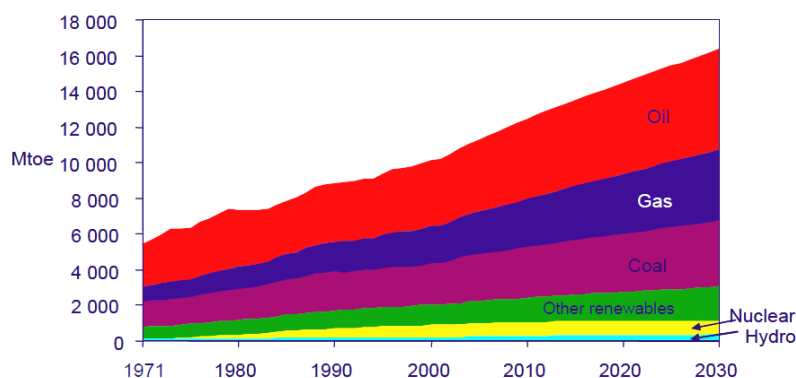
#### **Box 12: The desirable benefits of mobility**

### ***2.2.2 Concerning trends: impacts and threats***

So far, mobility’s general benefits are discussed. In reality however, abundant scientific research confirms that improved mobility has come at a price, and both authorities and society are increasingly aware of that. As a result, the ecological and environmental effects of mobility are high on the agenda in especially developed regions like Europe, Japan, and the USA. In addition, societal groups (e.g., Greenpeace) and worldwide media currently draw increasingly attention on adverse effects of mobility, effects that basically originate from the raw material that fuels modern mobility forward, crude oil.

### Resource availability

For decades, the transportation sector relies almost entirely on the mere availability of petroleum fuels like gasoline, diesel, and jet kerosene.<sup>9</sup> These energy carriers are derivatives from crude oil, a finite fossil natural resource that is used as source and carrier of energy, worldwide. A concerning trend is reported by the reference scenario in the 2005 World Energy Outlook report. Mainly due to the expected high grow-rates of population and economics in the developing regions, the world's energy needs will be more than 50% higher in 2030 than today (WEO 2005). In this view, crude oil would then have an approximated share of over 35% (fig. 6). A continuation of this trend will make Europe dependent on imports from third countries for 90% of all its oil requirements (EC/COM/265 2005; Steenberghen & López 2007). The dependency on geopolitical instable regions makes the transport sector extra vulnerable.



**Figure 6: Projection world primary energy demand (WEO 2005)**

As can be seen in appendix C, since 1970 the price of crude oil (expressed in 2006 US dollars) ranged from a low \$10 to a high \$65 per barrel with fluctuations over short time intervals. Due to ongoing political forces, economical interests and imbalances between supply and demand, price instability is likely to continue. Predictions of future oil prices are uncertain since “there has been little ‘trend’ for guidance about the future” (WBCSD 2001: p.2-14). Although predictions about earth's oil reserves differ much, many analysts expect that the dominance of transportation fuels derived from crude oil will decline at some time in the future. Therefore, resource availability is an enduring and global concern since the fuel that currently drives virtually the entire transportation sector is not capable to satisfy the increasing demand indefinitely.

### Environment

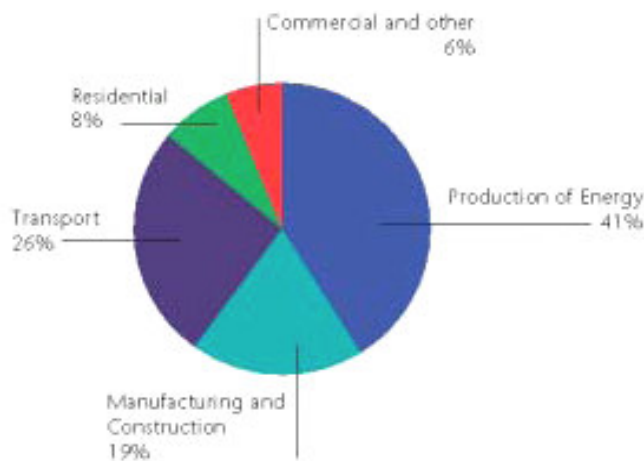
Unfortunately, there are more drawbacks about transportation fuels derived from crude oil. In 2003, the American Geophysical Union, an international scientific research group with more than 45,000 members, concluded that the increased global near-surface temperatures observed during the second half of the 20<sup>th</sup> century coincide with the increasing concentrations of GHGs (AGU 2003). Furthermore, especially the burning of fossil fuels (e.g., the process in internal combustion engines (ICE)) and worldwide deforestation increase the concentration of atmospheric carbon dioxide (CO<sub>2</sub>) and other GHGs (e.g., AGU 2003; Tolan & Berzon 2005). Hence, transport-related activities rise GHGs significantly, which in turn result in negative environmental effects like climate change, global

<sup>9</sup> 98% of the transport sector is dependent on products derived from crude oil (EC 2005).



warming, stratospheric ozone depletion, melting glaciers, droughts, floods, and rising sea level (e.g., AGU 2003; WBCSD 2001 & 2004; WEO 2005).

But what exactly is transportation's share in this context? According to the Energy Information Administration, transport is with its 26% share the second biggest source of CO<sub>2</sub> emissions after power generation, worldwide (fig. 7) (EIA/DOE 2000). In Europe, similar figures exist. Calculations performed by the European Commission (EC) estimate that transportation is responsible for at least 21% of all anthropogenic GHGs (EC/COM 2006). Moreover, this number is still rising rapidly. Combined with the explosive grow-rates currently measured in the developing regions, the negative global environmental effects caused by transport form an alarming threat. Vergragt (2004: p.14) even poses that if present trends of growing global population and increased mobility continue without actions to reduce or compensate transport-related negative effects, "there will be a global ecological disaster."



**Figure 7: Share of worldwide CO<sub>2</sub> emissions from fuel combustion per sector (EIA/DOE 2000)**

### Local effects

So far, universal concerns are highlighted. From a local perspective, transport-related activities can cause significant impacts too. These include among others toxic urban air pollution, acidification, traffic congestion, excessive noise, accidents, injuries, and land use. To some extent specific solutions can mitigate these problems (e.g., additional roadways, noise barriers). Though, Friedl & Steininger (2002) argue that over the next decades the negative local site effects will further intensify with the expected growth in transport and population. Furthermore, adverse local effects (e.g., traffic congestion resulting from a mismatch between available road capacity and the amount of traffic at a given time) can be a great threat to the transport system itself. Solutions for the negative local effects are costly and reduce the system's overall benefits, which in turn might slow down economic growth.

### **2.2.3 The quandary**

It has become clear that the merits modern mobility brings come at a price. The increasing global and local drawbacks are in discordance with the interrelated 'cornerstones' environmental stewardship, social responsibility, and economic prosperity; principal goals commonly thought necessary for

sustainable development (Placet, Anderson & Fowler 2005).<sup>10</sup> The mismatch between the current road mobility system and the concept of sustainability in fact illuminates macro-level pressures to change the system. Efforts that mitigate the problems associated with current forms of transportation are thus needed. Fortunately, bit by bit regulations are altered, public's awareness rises, and initiatives and (pilot) projects have started all over the world that aim for a mobility system that is more efficient, equitable and technologically advanced, and less environmentally and socially disruptive (SMP 2004). These efforts are discussed in the next section and reveal emerging opportunities on the micro-level that stimulate and may initiate the desired transition process. In sum the section's viewpoint:

Since humankind, mobility in all its forms serves society to survive. To date, society becomes increasingly aware of adverse effects that come along with improved mobility as it is known today, effects that ultimately reduce quality of live. Future viability of mobility is only then secured when the challenges associated with current means of transportation are addressed effectively (i.e., in a sustainable manner), while preserving the characteristics that make mobility so desirable.

**Box 13: Statement about mobility**

This statement is in line with the mobility dilemma as defined by WBCSD (2004): “global society faces a major dilemma. The world’s present mobility trajectory is unsustainable. As the need and demand for mobility continue to grow worldwide, it has become clear that mobility, as we know it today, must change, if it is to become sustainable. Moreover, achieving sustainable mobility by mid-century will require contributions from all stakeholders.”

By now, the general mobility dilemma is discussed. Besides, it is demonstrated why this dilemma should be treated as highly relevant. However, it still remains fuzzy about how (on a micro-level), by whom, and when the dilemma can be approached and resolved. The mobility dilemma already poses that efforts from all stakeholders are necessary in order to realize sustainable mobility by the year 2050. The next section elaborates on specific challenges, stakeholders' contributions, and potential means that aim to address sustainable mobility issues from a road transportation perspective.

## 2.3 Challenges

### 2.3.1 Indicators and goals

Since the end of the 20<sup>th</sup> century, numerous reports and scientific articles have been written that elaborate on sustainable mobility issues. Some focus on environmental and socio-economic aspects (e.g., Friedl & Steininger 2002; Eldomyaty et al. 2007), others underscore technology's role (e.g., MacLean & Lave 2003; Ryan, Convery & Ferreira 2006), and several pursue an integrated approach (e.g., Nicolas, Pochet & Poimboeuf 2003; Haynes, Gifford & Pelletiere 2005; Turton 2006). Content-wise, contributions are usually made by research scientists, research organizations, governmental bodies, and relevant companies. Apart from the many different perspectives and criteria, indicators

---

<sup>10</sup> Definitions about sustainability abound in literature. Probably the most famous stems from the Gro Harlem Brundtland Commission in the UN's report Our Common Future (Brundtland 1987: p.54): “Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

and goals are often presented that enable a judgment of the current and possible future state of mobility. Quantifiable indicators make it possible to evaluate the effectiveness of various improvement approaches. Table 1 summarizes indicators that reflect sustainable mobility's elements. The entire set stems from the influential international report 'Mobility 2030'.

**Table 1: Indicators and goals for sustainable mobility (WBCSD 2004)**

Indicators	Goals
Accessibility; Financial outlay required of users; Travel time; Reliability; Safety; Security; Greenhouse gas emissions; Impact on the environment & on public well-being; Resource use; Equity implications; Impact on public revenues & expenditures; Prospective rate of return to private business	Reduce transport-related GHGs to levels such that they cannot be considered a serious public health concern anywhere in the world; Limit transport-related GHGs to sustainable levels; Significantly reduce the worldwide number of deaths and serious injuries from road crashes. Efforts to do this are particularly needed in the rapid motorizing countries of the developing world; Reduce transport-related noise; Mitigate transport-related congestion; Narrow the mobility 'divides' that exist today (a) between the average citizen of the world's poorest and the average citizen of the wealthier countries, and (b) between disadvantaged groups and the average citizen within most countries; Preserve and enhance mobility opportunities available to the general population

This set immediately reveals the diversity of sustainable mobility. And indeed, this affirms the concept's complexity as suggested in the chapter's introduction. Many indicators reflect umbrella measures. For instance, 'resource use' consists of the three sub-factors (1) transport-related energy use and energy security, (2) transport-related land use, and (3) transport-related materials use. Although each individual indicator seems rational and partly irreducible from one another, interest conflicts may arise when some indicators simultaneously are taken into account. For example, increasing safety requires increasing weight, which lowers fuel economy. Lighten materials is then an option, though, costs will increase. Also, decreasing GHGs generally decreases engine efficiency (MacLean & Lave, 2003). Obviously, inevitable trade-offs are necessary. Nonetheless, Nicolas, Pochet & Poinboeuf (2003) demonstrate in their case-study about sustainable road mobility that improvements can actually be realized concurrently along each pillar of sustainability. Above all, according to WBCSD (2004), the indicators ought to be central to any vision of sustainable mobility and the route to get there, and that is the reason to present the set of indicators in this report.

After an assessment of all indicators WBCSD (2004: p.58) concluded: "it appears that today's system of mobility is not sustainable. Nor it is likely to become so if present trends continue". As a result, seven goals are proposed that improve the outlook for sustainable mobility (table 1). These goals must be considered as aspirations towards efforts should be directed. From this point onwards, the report's focus is set more towards the environmental needs as discussed in the definition of sustainable mobility presented before in footnote 8.

### **2.3.2 Act in conjunction**

In general, the goals clarify what actions can be fulfilled. But by whom, and how can these goals be pursued? To date, organizations, research institutions, policy makers among many others are increasingly engaged in solving parts of the sustainable mobility dilemma. Undeniable, significant

progress has been made last years (e.g., lead-free fuels, introduction of HEVs<sup>11</sup> and FFVs<sup>12</sup>, intelligent transport systems), and exploring long-term research continues (e.g., hydrogen and fuel cell technology). However, the challenges are far too complex to tackle all at once. From this perspective, ‘global policy networks’ as proposed by the United Nations form the foundation for global sustainability challenges. Such network is characterized as: “a coalition for change which bring together international institutions, civil society and private sector organizations, and national governments, in pursuit of common goals” (UN 2000: p.70). Obviously, the common goal in this context is sustainable mobility.

### Novelties and building blocks

Currently, such global networks are formed that aim for sustainable mobility. International alliances are formed between governmental bodies, research organizations, and industries throughout the complete value-chain. The joined forces and interactions between the stakeholders contribute to a common understanding of how challenges can be addressed effectively. Moreover, such network is capable to modify embedded structures and practices significantly, and to develop and introduce novelties on a large-scale. An early example is the 1990 Clean Air Act<sup>13</sup> legislation that banned leaded fuels since they cause serious environmental and health damage. In the developed regions the phase out of lead from gasoline finished in 1996. The International Fuel Quality Center estimates that around 80 countries (mainly located in East Europe and Africa) still supply leaded gasoline, though the total leaded gasoline volume is less than 10% of the global pool (IFQC 2002). As a result of this act, oil companies introduced lead substitute additives to remain high octane levels, car manufacturers modified engines, and the lead-free fuels opened up the large-scale market for catalytic converters which reduce negative emissions even further.

Clearly, the large-scale introduction of breakthrough novelties requires cross-business and cross-border cooperation. The novelties, often consisting of (radical) product and process innovations, are the indispensable building blocks<sup>14</sup> to overcome sustainable road mobility’s challenges (e.g., Hekkert & Hoed 2004; WBCSD 2004). In order to be more specific about the network and building blocks, the following sub-sections zoom in on stakeholders’ involvement and their contributions toward more environmentally sustainable road transportation. The stakeholders are categorized into three general groups, i.e., (1) political institutions, (2) industry and other NGOs<sup>15</sup>, and (3) society.

### Political institutions

Central governments commit themselves with regulating and administering many areas of human activity. In addition, they have the authority to make and enforce rules and laws within states, countries, and international regions such as the EU. To date, governmental bodies worldwide gradually adopt novel strategies and regulations to keep on track reaching Kyoto Protocol targets.<sup>16</sup>

---

<sup>11</sup> HEVs (hybrid electric vehicles) possess a regular ICE, generator, battery and an electric motor. The combination with an advanced energy management system makes the vehicle more fuel efficient. To date, Toyota, Honda and Lexus sell HEVs in Europe. Shortly, brands like VW, Porsche, Volvo, Citroën, BMW, among many others will introduce HEVs.

<sup>12</sup> FFVs (flexible fuel vehicles) possess an ICE that can be fueled with variable mixtures up to 85 volumetric % of biofuel (ethanol) and 15 volumetric % of gasoline. To date, Volvo, Ford and Saab sell FFVs in Europe.

<sup>13</sup> For further information about Clean Air Act see: [http://www.epa.gov/air/oaqps/peg\\_caa/pegcaa04.html#topic4a](http://www.epa.gov/air/oaqps/peg_caa/pegcaa04.html#topic4a).

<sup>14</sup> Building block is “something that has the potential to generate change if it is utilized effectively” (WBCSD 2004: p.145).

<sup>15</sup> NGOs is an acronym for non-governmental organizations.

<sup>16</sup> “The Kyoto Protocol is an agreement under which industrialized countries will reduce their collective emissions of greenhouse gases ... limitations range from 8% reductions for the European Union and some others to 7% for the US, 6%.

As far as road mobility concerns, regulations have mainly concentrated on controlling the negative impacts of vehicle use (e.g., exhaust emission laws, fiscal measures, congestion and access charges (London)). Furthermore, political institutions assess (alternative) transportation modes and technologies, and determine which is supported and (economically) favored through subsidies. Additionally, regulators possess the power to penalize, or even prevent car manufacturers from selling undesirable cars, or fuel suppliers from selling undesirable fuels. The legislative frameworks start to pay off and for example improve air quality substantially in several cities (Tzeng, Lin & Opricovic 2005). Probably the most progressive environmental regulation to date is adopted by the US state of California. The so-called ‘zero-emissions vehicles (ZEV) mandate’ commands that in 2009 of all new vehicles offered for sale, <1% are ZEVs, 5% are advanced technology partial ZEVs (e.g., HEVs and FFVs), and 30% are partial ZEVs (i.e., conventional vehicles certified to the most stringent tailpipe emission standards) (CARB 2007). Despite the mandate’s progressive objectives, critics are found in literature too, given that only tank-to-wheel emissions are taken into account, and well-to-tank emissions are completely neglected (e.g., MacLean & Lave 2003).<sup>17</sup> However, since 1990 the Californian environmental regulatory context stimulates the development of alternatives to conventional ICE vehicles (Hekkert & Hoed 2004). As a result of the CAFE<sup>18</sup> requirements, more than five million FFVs were produced for the US market from 1992 to 2005 (EIA/AEO 2007), clearly indicating that the regulatory framework can induce the adoption and diffusion of environmentally benign alternative. Table 2 elaborates on several short-term strategies recently proposed by the EC to improve the outlook for the road mobility system from an environmental perspective.

**Table 2: Short-term strategies for EU legislative framework, cutting GHGs from cars (EC/IP/07/155 2007)**

---

**EU strategies**

---

Encourage car industry to compete on the basis of fuel efficiency instead of size and power;  
 Introduction of an EU code of good practice on car marketing and advertising;  
 Fiscal measures that encourage the purchase of fuel efficient cars and discourage fuel inefficiency;  
 Encourage complementary efficiency improvements (tires, air-conditioning, biofuels, filters etc.);  
 Support for research efforts aimed at further reducing GHGs from road transportation

---

Furthermore, many (central) governments support pilot/validation projects with (financial) resources, and stimulate efficient mobility utilization (e.g., mass public transportation means, chain mobility services, car sharing programs). In this context, Switzerland is a primary example of replacement of personal cars with a highly efficient mass public transport system (Lienin, Kasimir, Stulz & Wokaun 2005).

---

for Japan, and permitted increases of 8% for Australia and 10% for Iceland” (UNEP press release via: <http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=412&ArticleID=4669&l=en>).

<sup>17</sup> Tank-to-wheel: Accounting of the energy consumption and GHGs resulting from moving the vehicle through its drive cycle. Well-to-tank: Accounting of energy consumption and GHGs over the entire fuel pathway, from feedstock to fuel dispenser nozzle. Furthermore, well-to-wheel denotes the combination of the fuel and vehicle portions (GM 2007).

<sup>18</sup> The Corporate Average Fuel Economy (CAFE) program is initiated in 1975 as part of America’s Energy Policy and Conservation Act. The aim of this program is to reduce the consumption of gasoline and thus the need for oil imports. Beginning with the 1978 auto model year, the program required all auto manufacturers to maintain certain minimum fuel economy averages for their fleets of vehicles sold in the U.S. The standard for passenger cars was set initially at 18 miles per gallon in 1978, but since has risen to the current 27.5 mpg. (EIA/AEO 2007: p.57).

An interesting approach is initiated by the Dutch government who recognizes that persistent environmental problems (e.g., global sustainability issues) cannot be resolved by traditional policies or by technological innovations alone. As part of its environmental policy repertoire, a transition policy and management system is adopted that follows a two-track strategy (Vergragt 2004; VROMraad 2004). The first track strengthens international policy ties whereas the second track an active national approach promotes. In the realm of sustainable road mobility, the Dutch transition management policy stresses the importance of collaboration in which industries, research organizations, society and the government take the lead (SenterNovem 2007). Government's role is central and ranges from content specific coordination, to process guiding efforts (VROMraad 2004). In fact, they orchestrate during transitions towards sustainability.<sup>19</sup> This approach is aligned with UN's vision about global sustainable development. These days, the Dutch government is seriously engaged and subsidizes sustainable road mobility pilots and research projects across different technologies and modes of transportation (e.g., BEST, Phileas<sup>20</sup>). Furthermore, the Dutch taxation policy financially privileges users of less emitting vehicles, and plans are proposed to levy extra taxes on high emitting vehicles.

#### Industry and other NGOs

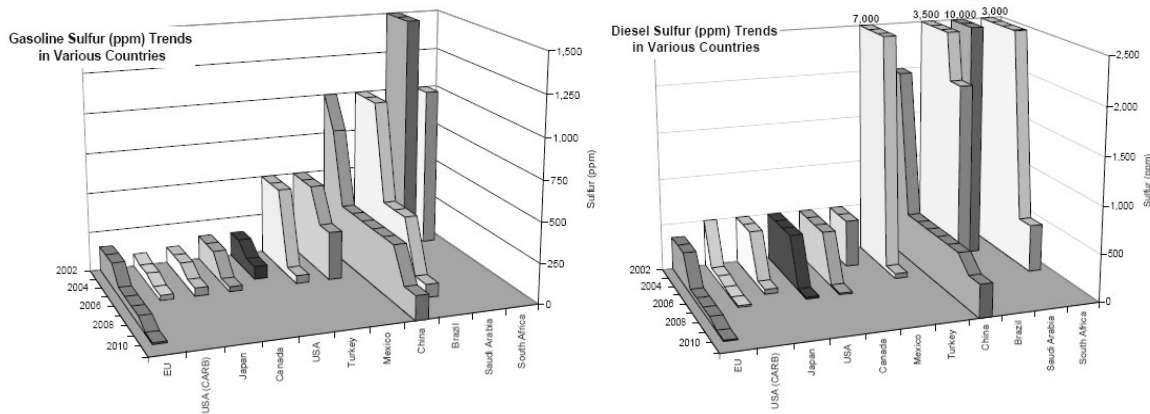
The growing stringent standards for emissions raise pressure on industry-level, and require vehicle manufacturers increasingly to look for (technological) alternatives. To date, especially the road transportation industry faces major GHGs-related challenges. As a result, they continuously invest huge R&D resources in further product improvements and in developing (radically) new propulsion systems (OICA 2002). In 1995, a collective voluntary agreement was signed between European, Korean and Japanese car manufacturers to reduce CO<sub>2</sub> emissions by 25% within 10 years.<sup>21</sup> This appeared to be a major driver to increase efficiency and develop (frequently under well-competitive conditions) new technologies like direct injection, particle filters, common rail diesels and HEVs. EC calculations report an average emission reduction in that period from 186 to 163 grams CO<sub>2</sub>/km. from new cars sold in the EU-15 (EC IP/07/155 2007), a reduction of 'merely' 13%. However, steps forward are realized, and the latest EC objective is to reach an average CO<sub>2</sub> emission of 120 grams/km. by 2012. Besides the automotive industry, oil companies have to deal with increasing stringent regulations too. After the gasoline lead-ban in the early 1990s, the more recent drive in fuel quality improvement focuses on sulfur reductions. Sulfur in diesel and gasoline fuels is found to be the main contributor to sulfur dioxide and particulate matter emissions. Also, sulfur is found to reduce the efficiency of exhaust after-treatment systems that are essential to meet future emission requirements (IFQC 2002). Figure 8 indicates that the degree of required reduction in sulfur levels varies around the world. Nevertheless, following the trend in both graphs, one might state that worldwide transportation fuels will be virtually sulfur-free soon.

---

<sup>19</sup> Chapter 4 discusses transitions and the transition management system more in-depth.

<sup>20</sup> Phileas is a mass public transportation project in Eindhoven covering buses equipped with a hybrid propulsion system consisting of LPG combustion engine, electric motor/generator and batteries. Overall these buses are 30% more fuel efficient, see for more information: <http://www.phileas.nl>.

<sup>21</sup> See for more information about the collective voluntary agreement: [http://ec.europa.eu/environment/co2/co2\\_home.htm](http://ec.europa.eu/environment/co2/co2_home.htm).



**Figure 8: Sulfur trends in gasoline and diesel in different countries/regions (IFQC 2002)**

In developed countries where vehicles have to follow the most advanced emission limitations for NO<sub>x</sub> and CO<sub>2</sub>, ultra low sulfur fuels have been requested by the automotive industry. The ‘Clean Diesel Fuel Alliance’ is such organization in which different industry sectors together opt for more environmentally friendly transportation fuels (EPA/ULSD 2007). From this point of view, one may conclude that profit-driven industries, often in collaboration with each other, create the essential technological (r)evolutionary building blocks to satisfy both, fuel- and fuel efficiency-regulations.

Besides the increasing stringent environmental regulations, the increasing public acceptance and consumers’ willingness to buy environmental friendly products form a second major driver for industries and other NGOs to invest in more sustainable road mobility products and processes. For instance, recent data shows a global growth spurt in HEVs production, and several companies are benefiting from a consumer trend towards fuel efficiency and environmental concerns over the past couple of years (e.g., Toyota, Honda). Also American and European car manufacturers invest R&D resources into the hybrid technology. For example, Ford’s company goal is to increase hybrid production tenfold, to 250,000 hybrids per year by 2010.<sup>22</sup> Volkswagen, Audi and Porsche formed an alliance to develop hybrid engines, and BMW joined General Motors and DaimlerChrysler in a similar partnership (Associated Press 2005). In sum, it appears that the mainstream car manufacturers embrace the hybrid technology and are pushing to offer hybrid options to consumers.

Long (1997: p.16) argues that the broad public support opens up a range of new opportunities for policy-makers to enter into voluntary agreements with industry, under which industry senses that it is possible to be clean, competitive and profitable, and is even “willing to commit itself to go beyond regulation”. This for obvious reasons, turns to good account in favor of the sustainable road mobility transition. According to Hekkert and Hoed (2004), two routes are currently followed by industries. The incremental route involves product improvements to increase efficiency and lower emission levels. The incremental innovations are in-line with user functions and compatible with existing products, processes and infrastructures. The breakthrough route on the other hand, revolves around radically new (zero emissions) technologies, often incompatible with current systems (e.g., conventional gasoline and diesel infrastructure). From a strategic business management perspective, most vehicle manufacturers balance their R&D resources between both routes. Even major oil companies (e.g., Shell) invest in long-term alternatives like hydrogen and biofuels as energy carrier.

<sup>22</sup> Via: <http://www.forbes.com>.

## Society

In democratic regions, policy-makers basically represent society to a large extent. As a result, citizens and societal interest groups exert influence on political programs. Also during sustainable development and transition processes, societies (e.g., consumers) act as crucial stakeholders since they form the necessary demand-side. In addition, they choose whether novel building blocks are embraced or not, and thus ultimately decide about their *raison d'être*. In general, consumers in developed regions are relatively satisfied with their current means of transportation. Shifting to other modes or technologies requires therefore superior performance and/or improved user functionality from the alternatives, or current means have to be seen as less desirable (MacLean & Lave 2003).

The Dutch government acknowledges the persistent role of society during (sustainable) policy-making and has adopted a strategy that works from outside to inside. VROM explains in the Policy with Citizens program (2005) that citizen-participation consists of consulting, advising, and co-producing. Accordingly, citizens' influence on policy intensifies because they are able to (1) act as expert or react on policy proposals, (2) give advice about how (parts of) policy can be shaped, and (3) are allowed to participate during agenda formation, problem definition and the actual policy-realization.

Industries too increasingly involve potential end-users during their research and development activities. Recent product development studies advocate that such strategy a better understanding of customers' behavior, needs and wants facilitates, which eventually can result in competitive advantage, quicker time-to-market, and reduced investment risks (e.g., Brombacher, Sander, Sonnemans & Rouvroye 2004). Clearly in the context of sustainable mobility, societies' interests are significant. Their full support can create economies-of-scale and commercial market success for any future building block, an essential prerequisite for successful initiation of sustainability transitions.

### **2.3.3 Obstacles of structural nature**

For years, virtually all stakeholders acknowledge sustainable mobility's relevance. Despite their broad support and positive agreement on the necessity to change, the transition processes to alternatives proceed relatively slow. For obvious reasons, one might accredit the moderate pace to the universal complexity of the sustainable mobility concept, the absence of a 'silver bullet solution', the multifarious interests, and the fact that it is not at all clear if there will be a stable final state and what it will look like. Uncertainty and different perceptions seem to be general barriers for a rapid transition process. Additionally, MacLean & Lave (2003) argue that road transportation alternatives face immense difficulties because of the success of conventional crude oil-based fuels, the dominance of ICEs, and the immense investments in the infrastructures required for developing alternatives and bringing them to mainstream markets. The next chapter focuses more in-depth on the factors that impede the desired road mobility transition. For now, two evident mechanisms found in literature are discussed that play a role and form obstacles of structural nature during sustainability transitions.

### Chicken-and-egg dilemma

The chicken or the egg is a reference to the causality dilemma which arises from the expression 'which came first, the chicken or the egg?' The chicken-and-egg dilemma is often appealed to in



pointing out the futility of identifying the original cause in any issue of cyclical cause-and-effect.<sup>23</sup> However, there are many real world examples of cyclical cause-and-effect. For example, fear of economic downturn cause people to spend less, which in turn reduces demand, causing economic downturn. But also, more jobs cause more consumption, which requires more production, and thus more jobs. In the realm of sustainable road mobility such mechanisms exist too. The Dutch government is aware of that, and argues that the chicken-and-egg problem (no demand, then no supply, thus no demand) forms one of the major barriers for alternative transportation fuels and propulsion systems to reach the market, in spite of the fact that a lot of options are already technologically feasible (SenterNovem 2007). This is confirmed by Vergragt & Brown (2007: p.1106) who argue that “without a consensus around the fuel question, both petroleum companies and most governments are reluctant to invest in infrastructure, preferring in stead the ‘wait-and-see’ attitude”, which in turn of course creates the chicken-and-egg dilemma. In general, the creation of favorable market conditions (market creation) by for instance governmental bodies may serve as means to break through the dilemma. Chapter 5 (Q4) elaborates more in-depth about the establishment of this strategy.

### Prisoners’ dilemma

The prisoners' dilemma is a traditional model for studying decision making and self-interest (Golbeck 2002). It has been studied extensively to model social behavior from individuals to communities.<sup>24</sup> The dilemma’s premise is that the only concern is maximizing the own payoff, without any concern for the other’s payoff, and that such strategy can have undesirable outcomes for everybody. Krusch (1994: p.6 & 8) describes many simple examples from real-life. For example, “a club has a fire, and all rush for the exits, preventing the exit of anyone. As a result, all perish”, and “drivers who don’t wear seat belts, thus driving up the cost of everyone else’s insurance”. As far as sustainable road mobility concerns, one might state that the air pollution which results from the collective actions of individual drivers, who believe that their own act of driving doesn’t matter, resulting in air that no one wants to breathe. Besides society and industries, governments are amenable for the prisoners’ dilemma too. VROM affirms that this dilemma bothers many countries since the costs associated with improving the sustainability outlook (e.g., reduction of GHGs) are for the initiator (one country), whereas the likes are worthy for everybody (all countries) (VROMraad 2004). Overcoming this dilemma requires adequate international mutual cooperation, a strategy that also in theory is perceived as the best long-term option for everybody. How this may look like from a sustainable road mobility perspective is further discussed in chapter 5 (Q4) too.

## **2.4 Discussion of research question 1**

### ***2.4.1 Introduction***

The chapter’s aim is to provide a basis for answering research question 1. This is done by discussing the mobility dilemma, trends, stakeholders’ contribution, and general mechanisms that exert influence on, and shape our (global) road mobility system as it is known today. In this context, a special focus is

---

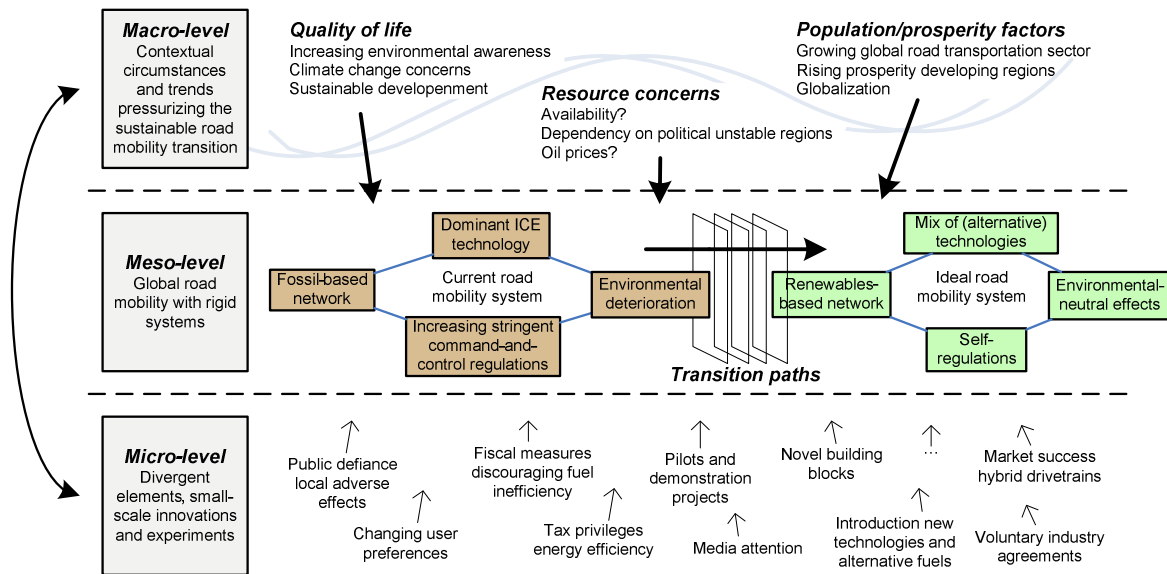
<sup>23</sup> Via: [http://en.wikipedia.org/wiki/The\\_chicken\\_or\\_the\\_egg](http://en.wikipedia.org/wiki/The_chicken_or_the_egg).

<sup>24</sup> An article by Krusch (1994) provides an excellent overview of the prisoners’ dilemma and its backgrounds.

given to the role of policy makers and measures, industries, and society in the quest to reduce the environmental burden from road transport-related activities. The next sub-section elaborates on research question 1, i.e., “what mechanisms on macro- and micro-level currently pressurize, and thus stimulate, the transition towards a more sustainable road mobility system?” Additionally, the answer is conceptually visualized in figure 9.

#### **2.4.2 Elaboration Q1**

This chapter revealed that to date deeply rooted contextual circumstances and concerning trends on a macro-level pressurize the global road mobility system to become more sustainable. A common characteristic on this highest level is that the trends and events proceed slowly in pace and are not, or hardly, to influence. First of all, society’s concerns about climate change go upward, especially in the developed regions. Not only on a political level, but also profit-driven industries and citizens more and more realize that the increasing environmental deterioration due to common everyday practices is unacceptable, and alterations are perceived necessary. As a result, the concept of sustainable development is increasingly applied (as legal obligation or on a voluntary base), also significantly within road transportation. Furthermore, the indispensable mobility system depends for decades almost entirely on crude oil-based products. Consequently, concerns about resource availability due to the reliance on instable regions are also evident on the highest level. This is further strengthened by unpredictable oil price fluctuations which form potential worldwide economic threats. The rapid growth of the global transport sector is caused by globalization and the rising prosperity in developing regions, which in turn increase the negative environmental impacts resulting from that sector. The combined contextual and cross-border circumstances on the macro-level create multiple interacting and intensifying mechanisms between policies, regulations, industries, and society. Together these provide sufficient momentum to initiate and indeed stimulate the transition towards a more sustainable road mobility system. The Kyoto Protocol, the EU Biofuels Directive, voluntary industry agreements, the adoption of environmental management systems for organizations like ISO 14000, the ZEV-mandate, and the increasing stringent emission standards and related tax structures are some important examples currently active that promote more sustainable practices in light of the road mobility system. Following the three transition levels model as discussed in sub-section 1.3.1, the macro-level pressures open up opportunities on a micro-level for small-scale technological experiments and innovations, but also novel taxation structures and public’s utterance become visible at this level. Figure 9 conceptually visualizes some important elements on macro- and micro-level that pressurize the desired transition process on the meso-level. At the macro-level three interrelated groups can be identified, i.e., quality of live, resource concerns, and population/prosperity factors. Finally, an ideal model for the desired road mobility system is also portrayed at the meso-level, and can be reached by going through various transition paths.



**Figure 9: Conceptualization of current macro- and micro-level pressures that create momentum and stimulate the sustainable road mobility transition on the meso-level**

### 2.4.3 Concluding words

The unsustainability of present trajectories in the road transportation sector is widely recognized. This chapter elucidated on this subject by underscoring the necessity to transform into a sustainable road mobility system. Additionally, it appeared that macro-level pressures to date shape indeed sufficient momentum to at least initiate the long-term transition process, an assertion which is confirmed by movements currently visible and tangible at the micro- and meso-level.

However, achieving such mobility system in a global-scaled dimension requires substantial efforts from all stakeholders, time, and a dazzling multitude of changes. Moreover, plentiful barriers and obstacles of structural nature have to be overcome, and it is far from clear how this actually may be managed in practice efficiently. The subsequent two chapters try to explicate these questions, first by presenting a set of factors that impede the transition process in the following chapter. Consequently, chapter four provides a conceptual approach intended to deal with the barriers and challenges of the road mobility system.

## **3 Barriers for novel building blocks**

### **3.1 Introduction**

#### ***3.1.1 Aims and structure of this chapter***

Promising new technologies are elements inherently connected with long-term energy sustainability transition processes, also in light of the road mobility system. However, sustainable road transportation technologies fulfilling important user requirements in terms of costs and performance are mostly not at hand on the market, but remain in laboratory settings or small-scale niche applications. As a result, the desired transition is slowed down and unsustainable practices persist.

The rationale of research question 2 is to examine what type of impeding factors are at hand, and how these factors shape barriers that prevent large-scale exploitation of environmentally benign road transportation technologies in general (Q2A), and for biofuels specifically (Q2B). Consequently, this discussion provides a basis for the subsequent research questions, i.e., how to overcome these barriers? Structure-wise, the chapter addresses Q2A and Q2B successively.

#### ***3.1.2 Method of approach***

The inventory for Q2A stems from an elaborated literature research in the field of new product development/marketing strategies and innovation adoption/diffusion theories, after which these insights are related to the section's scope, i.e., sustainable road transportation technologies. The taxonomy of factors described in Q2A is used as basis for Q2B. The discussion of barriers specifically for biofuels stems partially from the case-study about biofuels as presented in appendix A. That study in turn is based on scientific articles and publications about biomass, bioenergy, and biofuels. Briefly, it provides a basic understanding of biofuels' historical developments, potential benefits, and critical issues to be addressed in order to exploit biofuels commercially on a worldwide-scale. Finally, where relevant and possible, the findings are linked with the situation in the Netherlands.

### **3.2 Discussion of research question 2A**

#### ***3.2.1 Introduction***

Within (personal) road mobility two major technology areas can be identified that, either by themselves or in conjunction, are able to contribute to sustainability, to be exact, transportation fuels and propulsion systems.<sup>25</sup> As a result, each of the impeding factors described below, revolve around one or both technological area(s). The elaboration in next sub-section addresses Q2A, i.e., “what type of factors form explicit barriers for the commercialization of sustainable road transportation technologies?”

---

<sup>25</sup> Appendix B provides a more elaborated overview of potential combinations of alternative transportation fuels and propulsion systems.

### **3.2.2 Elaboration Q2A**

#### Technological hurdles

A rational reason for rejection emerges when a new technology suffers from limited technological performance and/or reliability when it is being compared to the dominant design. Furthermore, a technology may be incapable to fulfill its aspired function on a large-scale and for a variety of end-users. Many technologies are initially developed under well-controlled laboratory settings. However, real-world introduction obliges the technology to fit in existing systems and markets too, i.e., in terms of user needs and expectations (Jobber & Fahy 2003). Anticipating on market reactions is therefore seen as crucial during product development, though, complicated (broad public thus broad set of different expectations), time-consuming thus costly, and often underestimated by industries operating in strong competitive environments. Consequently, due to neglected or inadequately performed consumer testing programs, unforeseen technological shortcomings may at first appear after large-scale market introduction. Expensive optimization or even specification-redesign efforts are then required, which ultimately threatens product/technology viability (Smith & Reinertsen 1998). The fundamental causes underlying the above presented risks and issues are a result of interrelated global trends recognized in product development and identified by Brombacher and de Graef (2001), namely (1) increasing technological product complexity, (2) increasing time-to-market pressures, (3) higher degrees of globalization and business processes and (4) increasing and diversifying customer requirements. Considering the automotive industry's current state of affairs, one might conclude that all these trends are highly relevant within that industry too. As a result, these trends ultimately restrain the development and introduction by industries of new sustainable road transportation technologies.

Secondly, the use of new technologies often requires complementary technologies or production processes that may still be immature or simply unavailable. These issues are highly applicable within, and experienced by, the automotive industry. For instance, the use of fuel cells for transport purposes is currently worldwide explored by research organizations (e.g., ECN) and car manufacturers (e.g., DaimlerChrysler). Although the fuel cell itself is relatively reliable, the necessary complementary technologies to store, distribute, and supply the hydrogen adequately in vehicles (in terms of convenience and safety) create huge technological and market barriers. Furthermore, technologies to produce hydrogen from renewable energy sources are only just in their infant research and development stages. Obviously these technological barriers delay large-scale market breakthrough for the promising sustainable fuel cell propulsion, but concerns other sustainable road transportation technologies too.

#### Supply, distribution infrastructures and maintenance networks

On the supply-side, the limited availability of sustainable primary energy sources forms barriers for the production of alternative fuels (e.g., biomass to produce biofuels, renewably generated electricity for hydrogen production). Furthermore, adaptation of infrastructures or even the establishment of new distribution systems may be required to enable large-scale market adoption and diffusion of alternative fuels. Within the road mobility system, a reliable, extended, and logistically well-organized fuel infrastructure is indispensable. As a result, this global scale network is optimized through a long-term process and according to current states of affairs (i.e., supply, distribution, delivery of conventional gasoline and diesel products). Characteristics of such globally organized

infrastructural systems are inflexibility, rigidity and the inability to cope with structural changes since that would require substantial (financial) investments. These investments in turn could only be yielded from a substantial vehicle fleet. As a result, large-scale diffusion and distribution of alternative and more environmentally benign transportation fuels (e.g., CNG, hydrogen, electricity) is hindered. Additionally, sunk-costs<sup>26</sup> are often inequitably pushed forward by current infrastructure's investors or other responsible stakeholders (e.g., oil-companies) to justify the resistance against novel, more sustainable alternatives.<sup>27</sup>

The maintenance network for the vehicle fleet is probably as rigid as the fuel infrastructure system. Service stations and mechanics have to be fully acquainted with new technologies in vehicles, to ensure adequate maintenance and repair. Obviously, a shift away from current practices in this network requires large investments and time too, all disadvantages for new technologies.

### Competency issues

Within the automotive industry, developing a new model from scratch to prototype to mass-production-ready product is a rather time-consuming and cumbersome trajectory. Hence, it is a risky process. On average, developing times from 28 to over 54 months are reported for vehicles, strongly dependent on type and brand (Smith & Reinertsen 1998). As a result, the automotive industry, and car manufacturers in particular, are relatively reluctant spending vast time and resources in radically new, and thus unfamiliar technologies (e.g., more sustainable propulsion systems) since they may delay developing cycle times even more.

Furthermore, established companies do not want to risk their core-competences becoming superfluous, a widely acknowledged and discussed topic in business management literature (e.g., Hamel & Prahalad 1994; Hoekstra & van Sluijs 2003). Also within the automotive industry, core-competences like ICEs and accompanying technologies more or less control and steer organizations in terms of research activities, production practices and even marketing strategies. For instance, BMW is globally renowned for its well-performing and reliable diesel and gasoline engines with in-line cylinder arrangement; a core-competence mastered through intense and long-term R&D investments. As a result, BMW 'protects' this profitable intellectual property through ongoing ICE optimization, clearly to the detriment of alternative propulsion systems. Furthermore, although many individual car manufacturers, or in allied partnerships, do invest in more sustainable technologies, they mostly lack or have limited competences to produce and market them for a large (non-niche) market. By all appearances, similar situations show up at international conglomerates like Shell and Standard Oil who are fully organized around their core-competence, fossil-based oil products. Since this is for decades virtually their only revenue generating product, room for alternatives like biofuels or renewably generated hydrogen is probably limited.

Thus in general, a focus away from familiar technologies (in this case unsustainable ICEs and fossil fuels) is from an economical and (short-term) strategic business perspective mostly unattractive and only done limited in R&D settings and niche projects, clearly obstructing large-scale introduction of alternatives.

---

<sup>26</sup> Sunk-costs are past investments made in existing systems.

<sup>27</sup> "One of the most difficult conceptual lessons that managers have to learn is that sunk costs are never relevant in decisions... regardless of the kind of sunk cost involved, the conclusion is always the same – sunk costs are not avoidable, and therefore they should be ignored in decisions" (Garrison, Noreen & Seal 2003: p.314).

### Political institutions and regulatory frameworks

As exposed in the previous chapter, in developed regions governmental bodies at different levels are committed to environmental protection. As a result, they often provide economic incentives to industries for R&D activities directed to sustainable development. Nevertheless, governmental policies may also form barriers in a sense that they often not put out a clear message for specific new technologies. For instance, in none of the countries investigated by Elzen, Hoogma & Schot (1996) there was a technology policy based on a clear view of the future, to guide technology developers, planners, and investors towards sustainable development. From this perspective, uncertainties about alternatives and their market potential may cause reserved attitudes by investors and researchers, obviously creating a chicken-and-egg dilemma for promising sustainable road transportation technologies.

Moreover, existing regulations and rules of the energy market are mostly based on decades of experiences with one monopoly system, in order to provide reliable energy availability (Reddy & Painuly 2004). Such strong international, ancient regulations obstruct breakthrough of modern alternative energy sources, and may even be inconsistent. For instance, the EU fuel quality directive limits the maximum blending of additives (e.g., ethanol) in petroleum-based gasoline and, by doing so, actually restricts ethanol's market share. On the other hand, the EU Biofuels Directive pleads for higher blending percentages of biofuels in common fossil-based fuels, resulting in conflicting legislations. A recent, more specific, example concerns a strict safety regulation in Italy,<sup>28</sup> which forbids the use of low ethanol-diesel blends in for instance public busses due to flash-point requirements of diesels (resulting in an increased risk of explosion).

International trade barriers caused by different tax incentives structures at national levels are another hampering factor, and hinder the opening of an international market (and thus competition) for alternative fuels. Furthermore, the lack of a common European standard forms serious barriers too. Such standards are a prerequisite for the approval of for instance liquid biofuels by car manufacturers and the public, whose confidence in the fuels' quality will be undermined without a quality stamp (Steenberghen & López 2007). Obviously, developing, or even changing, any regulatory framework is a cumbersome process, which in turn impedes the large-scale market penetration of new, more sustainable fuels. Nevertheless, proposals to reformulate such regulations are considered these days at for instance the European level (IEA/OECD 2004).

Besides the energy sector, the automotive industry deals with obstructing regulatory issues as well. For instance, the previously discussed Californian ZEV-mandate strongly stimulates the development of electric vehicles, conversely, discouraged at first the use of HEVs (Kemp, Schot & Hoogma 1998), despite the fact that the latter may be cleaner if well-to-wheel emissions are taken into account. As a result, hybrid technology suffered initially from negative advice by governmental bodies.

### Market demand

Anticipating on the innovation adoption decision by users is perceived as complex by organizations, because no prior experience on the buying process of the particular product/technology exists (Frambach 1993). In this respect, adoption choice of a new product or specific technology by end-

---

<sup>28</sup> Turned out during a BEST project meeting in Bilbao, 29<sup>th</sup> of Mai, 2007.

users is, among other factors, dependent on its price. The importance of the market demand factor 'price' is also reflected by the fact that this decision-making element is incorporated in the common-acknowledged '4-p marketing mix'. The application of new technologies is often expensive owing to its necessary extra R&D investments, and the fact that they have not yet benefited from production process optimization, economies-of-scale, and/or other efficiency-related learning effects (Lewis 1994). As a result, the relatively high unit costs of for instance new sustainable road transportation technologies are a disadvantage in the price competition-intensive automotive sector.

Perceived risk and uncertainty by end-users (resulting in a wait-and-see attitude) poses considerable barriers for the breakthrough of sustainable technologies, even in situations in which the user has carefully evaluated and considered adoption (Aggarwal, Cha & Wilemon 1998). Risk aversion by users may emerge due to the fact that they are not sure what to expect from new technologies since (1) these technologies have not proven their value and meaning at large-scale, and (2) specific and simple information about the technology lacks, which makes it difficult for users to make appropriate decisions.

The implications of new technologies in practice may form market demand barriers too. For instance, the use of LPG, a gaseous fuel believed to be cleaner, requires an extra tank (and thus space) in the vehicle. Furthermore, although the Dutch LPG infrastructure may be well-organized, across the border, the supply network is not as widely extended as in the Netherlands. Additionally, the cross-border LPG infrastructure is often incompatible with Dutch LPG systems, which obliges the user to reckon with.<sup>29</sup> These practical implications and convenience issues give reasons for the fact that some users do not accept a technology. Compatibility is one the five characteristics of an innovation identified by Rogers (1983), which have a relation to the degree of adoption of that innovation in a social system. Compatibility is defined as: "the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters" (Rogers, 1983: p. 226), and is positively related to the rate of adoption. As a result, the more incompatible a sustainable road transportation technology is within a situation and according the needs of potential adopters, the lower the probability that the innovation will be adopted. From this perspective, so-called 'gateway technologies' may solve incompatibility issues by making it technologically feasible to utilize two or more components/subsystems as compatible compliments within an integrated system (David & Bunn 1988). Nonetheless, they reduce convenience and increase costs.

Moreover, the aversion of users against certain new technologies may even be sufficient reason for organizations (e.g., car manufacturers and oil companies) not to market a specific environmentally friendly product or technology. Especially the automotive industry is a highly sensitive market in which a loss of market share, because of failed introduction, may cause severe image-related problems.<sup>30</sup> In sum one might conclude that manufacturers of existing technologies prefer to avoid market risks by building on current 'save' technologies, which in turn obstructs alternative, more sustainable technologies, also in the road mobility sector.

---

<sup>29</sup> Refueling LPG in Belgium requires an adapter between fuel supply unit and vehicle fuel inlet system. Such adapter is an example of a 'gateway technology device' that solves incompatibility issues.

<sup>30</sup> Failing to pass the 'Eland-test' by the Mercedes A resulted in bad publicity and costly adjustment measures for the company.



### Cultural and public perception

The introduction of the automobile at the beginning of the 20<sup>th</sup> century offered suddenly increased freedom on the road at any given time. At that time, and even to date, it became a symbol of modern life-style, fully packed with emotional feelings. According to Mom (1997), important cultural aspects were excitement, entertainment, adventure, speed, and contest for records. For many owners, cars are means to express their individual feelings and status. As a result, car manufacturers, salesmen and consumers shaped general ideas about how a car should look like and what it should be able to do, ideas that may not be in-line with modern alternative technologies that alter the well-known 'composition' of the car significantly. From this perspective, HEVs are by some users in discordance with existing believes that cars' sporting character can only be achieved by gasoline fueled ICEs.

### Objectionable societal and environmental effects

Although new and more sustainable technologies may be capable of solving for instance environmental-related problems, they may also introduce (unforeseen) negative adverse effects in other contexts (Sagasti & Sachs-Jeantet 1994). For instance, the use of biofuels produced from sugar cane reduces GHGs. However, the production of these fuels requires 'energy-crops' to grow on vast amounts of land, which in turn prevents the use of that land for other purposes (e.g., growing of crops for food). As a result, this trade-off conflicts by many people on an ethical dimension with famine situations in some less developed regions. In the area of vehicle propulsion, similar effects can be identified. For instance, HEVs require additional batteries to reach their efficiency advantages. Production and disposal of these batteries are inherently connected with increased environmental burden, something which reduces the overall benefit of HEVs.

In sum one might conclude that all advantages come with disadvantages. Quite some effort is required to find out what additional problems can be expected in other perspectives, and how they can be solved. In the mean time worldwide media often remains highly skeptical, affecting the image and market viability of new and more sustainable transportation technologies.

### **3.2.3 Concluding words**

The foregoing, and in all probability incomplete, elaboration reveals that many different factors form explicit large-scale entry barriers for sustainable road transportation technologies. In general, these factors cover either technological, market, societal or institutional issues. Economical/financial issues are at stake in virtually all factors, and are therefore not individually portrayed in the elaboration. As discussed in the previous chapter, many sustainable technologies are technically proven in small-scale controlled environments. As a result, predominantly non-technical factors form the key barriers and thus ultimately determine commercialization success at large-scale, something which is affirmed by Q2A's elaboration.

Also in view of other technologies and innovations, issues on the market-side heavily influence the rate of adoption and thus ultimately product/technology success. As a result, scientific research on diffusion of innovations has been the interest of many disciplines over the last few decades. In general, this research contributed to the understanding of new product adoption in the market. The process of adoption by users forms a key element in diffusion theory and can be clarified as the process which an individual goes through till the decision to adopt (i.e., buying a new product). This process is complex and influenced by many interrelated and subjective factors (Frambach, 1993).

A widely cited study on diffusion is that of Rogers (1983). According to the author, the rate of adoption of an innovation is positively affected by the innovation characteristics relative advantage, compatibility, trialability, observability, and negatively affected by complexity. This model is accepted by many empirical studies. Other studies go beyond this model and include also factors like risk aversion and uncertainty (Noteboom, 1989), and network externalities<sup>31</sup> (Farrell and Saloner 1986). In sum, factors that are all relevant and discussed in the previous outline about the impeding factors for sustainable technologies.

The main conclusion that can be drawn is that the discussed factors indeed form explicit barriers (but in varying magnitude), and affect the adoption and diffusion process of environmentally benign road transportation technologies. Furthermore, the factors act as an interrelated set on different levels (individual, society, organizational, political) that may enforce each other. Especially the dynamics and common practices in current stable systems (e.g., fuel infrastructure, regulatory frameworks) are an explanation for understanding the reduced probability of success of new technologies. Finally, particularly the ‘individual-related’ factors turn out to be highly sensitive for subjectivity, which adds up to the complexity of the problem. Table 3 summarizes the interrelated factors with brief descriptions that impede large-scale commercialization of sustainable road transportation technologies, and ultimately slow down the desired transition process in the road mobility system.

**Table 3: Important interrelated factors impeding large-scale commercialization of sustainable road transportation technologies**

<b>Factor</b>	<b>Description (examples)</b>
Technological hurdles	Insufficient technological performance compared to dominant design Incapability to fulfill the aspired function for a diversified large-scale market Necessary supplementary (gateway) technologies immature/unavailable
Supply, distribution infrastructures and maintenance networks	Insufficient availability suitable renewable energy sources, lacking infrastructure Inflexibility existing networks results in inability to cope with structural changes Investors and stakeholders act for own interests, e.g., sunk-costs
Competency issues	Shifts away from core-competences to unfamiliar technologies is a risky process Avoidance of market risks: failed introduction may result in image-problems
Political institutions and regulatory frameworks	No clear view/message for the future resulting in investment/market uncertainties Unavailable or conflicting (environmental) regulations at different levels Lacking necessary standards and international trade schemes
Market demand	Risk aversion and uncertainties by market/industry results in a wait-and-see attitude Higher unit prices of alternatives due to lack of learning effects Not accepted due to practical implications, e.g., incompatibility issues
Cultural and public perception	Discordance with existing believes, personal life-style, etc.
Objectionable societal and environmental effects	Undesirable effects on other dimensions

<sup>31</sup> Network externalities are gained in those situations where the value of a product or infrastructure increases by an increasing number of users that adopt the product.

### 3.3 Discussion of research question 2B

#### 3.3.1 Introduction

In this report, the term ‘biofuel’ refers to a liquid fuel for uses in the road transportation sector, and that is predominantly produced from biomass feedstocks.<sup>32</sup> Past years, several biomass-derived alternatives have been assessed in detail. The general conclusion is that especially ethanol and biodiesel are the most promising options available in both the short and medium-long term. Global substitution of petroleum fuels by at least 30% with ethanol and biodiesel is feasible, in a social, economical, and ecological responsible way. The potential of these fuels is also reflected by the fact that both are central within the BEST project. To date, research programs over the world give much attention to both types of biofuel. The use of more efficient feedstock materials and conversion processes is being explored, as well as new applications for the fuels and its co-products. Any further information about the biofuels can be found in the case-study (app. A). This study serves too as point-of-departure for answering research question 2B, i.e., “how do the factors discussed in Q2A shape and affect barriers for the commercialization of biofuels in the Netherlands?”

#### 3.3.2 Elaboration Q2B

##### Technological hurdles

The long history of biofuels and devoted research activities resulted in an excellent technical understanding of the production of biofuels from various agricultural sources. Nevertheless, especially in industrialized countries experiments with new type of promising feedstocks (e.g., forestry and agricultural waste streams) continue, since these may yield additional economical, logistical and environmental benefits. General problems with the feedstocks of these second-generation biofuels are the physical and chemical properties (e.g., low density, high ash, moisture, nitrogen, sulfur content) that make it difficult and expensive to ensure end-quality of the biofuel (Lamers 2006). Furthermore, given the nature of biomass, the final density is still far less than that of for instance crude oil, resulting in relatively expensive transportation costs. From this perspective, research in pre-treatment densification technologies is desired, but still in its infant stages. Pyrolysis or torrefaction may be possibilities, but still need to be proven on a commercial scale (Faaij & Domac 2006).

The application of ethanol entails some concerns about its technical compatibility with existing vehicle fleets. First, in colder climates, minor technical problems arise such as cold start difficulties caused by lower vaporization pressures of ethanol blends, glow-plug-ignited fuel systems may solve these problems (Rosillo-Calle & Walter 2006). Second, doubts are related to metallic materials of the vehicle (corrosion) and chemical attacks on plastics and rubbers. However, this depends on the blending percentage and the technological level and age of the vehicle (Coelho, Goldemberg, Lucon, & Guardabassi (2006). According to the Brazilian automobile manufacturers association, small blends of ethanol (up to 5%) do not affect existing engines. Blending percentages above 5% may require vehicle modifications (ANFAVEA 2005). This introduces an important technical hurdle. To apply ethanol blends with any ratio above 5-10%, the flexible fuel technology is necessary. The incremental cost to produce vehicles fully compatible with E10 is estimated to be only

---

<sup>32</sup> See also footnote 3.

a few US dollars per vehicle. The extra cost for E10-E85 compatibility is estimated to be 100-200 US dollars (IEA/OECD 2004; Refocus 2006). Nevertheless, this is much lower than the several thousands of US dollars of incremental cost to produce vehicles running on for instance CNG or LPG. Although the number is increasing, to date, only few car manufacturers offer FFVs in Europe.<sup>33</sup> Thus, the very limited availability of complementary and gateway technologies impedes large-scale commercialization of biofuels, also in the Netherlands.

Biodiesel has a higher gel point than petroleum diesel which may make it more difficult to use in temperate regions in the winter. Additives are available for both biodiesel and petroleum diesel to make them flow better in cold temperatures, but petroleum diesel has a technical advantage in this area. Blending biodiesel with petroleum diesel as is done in France mitigates too the cold flow problem. Furthermore, biodiesel in its pure form is somewhat less stable in storage than petroleum diesel. As a result, vehicles running on biodiesel often have an extra fuel filter to remove sediments that accumulate from the oxidation of biodiesel. It is however worth mentioning, that petroleum diesel is also not 100% stable and does degrade in storage too.

#### Supply, distribution infrastructures and maintenance networks

A global key uncertainty is the availability of sufficient agricultural land to produce and harvest energy crops for large-scale expansion. Additionally, biomass production on a scale of this order of magnitude must address other sustainability aspects including water and soil management, nutrient recycling and preservation of organic matter (Turton 2006). Land availability and cheap biomass harvesting/production in the Netherlands are very limited. Furthermore, in most of the few countries able to supply biofuels to international markets, the tendency is to supply first the internal market rather than the cross-border markets (Rosillo-Calle & Walter 2006). As a result, feedstock availability and the utilization of biofuels in the Netherlands are highly dependent on (seemingly irrepressible) international developments in this sector.

Another issue that could limit the biofuels' viability is the required development of a well-organized and efficient intercontinental supply chain infrastructure for collecting, processing, and distributing large volumes of biofuels. Since ethanol can easily be contaminated by water, and biodiesel dissolves entrained residues, they cannot be blended at the refinery and batched through existing pipelines (EIA/AEO 2007). As a result, railroad cars and truck are needed from biofuel-compatible materials to transport large volumes to the market. A further seriously constraining matter is the fact that the local transportation in both, biomass exporting and importing may be a high cost factor, which influences the overall energy balance and total costs of biofuels (Faaij & Domac 2006).

Distribution to end-users is also hampering by a number of factors. The unique physical properties of high-blended biofuels (e.g., E85, B100 biodiesel) compared to traditional fossil fuels, require adaptation of existing equipment, or even new equipment at fuelling stations to store and dispense the biofuels.<sup>34</sup> Without appropriate financial support from for instance governmental bodies, (independent) fuelling station owners may be reluctant to invest in these adaptations or equipment.

---

<sup>33</sup> See footnote 11 for these manufacturers.

<sup>34</sup> Turned out during a BEST project meeting in Bilbao (2007).

### Competency issues

As discussed in Q2A, one might assume that major oil companies prefer a wait-and-see attitude as far as biofuels concern, since they could reduce revenues from fossil fuels. However, this is difficult to assess because in fact substantial research activities are carried out these days by for instance Shell, in the field of renewables. On the other hand, oil companies currently advertise heavily in the developed countries with better performing (also environmentally-wise) fuels like Shell Pura, V-power, and BP's Ultimate fuels. From this perspective one might state that oil companies try to push a 'biofuel-counterpart' on the market that reckons with environmental issues too.

When it comes to establishing large-scale bioenergy and biofuel production systems, a combination of knowledge, skills, and institutional capacity is needed. Since the Netherlands has not a tradition in producing and using biofuels, the requirements for setting up a large-scale national biofuel system may not be abundant at hand. Furthermore, a lack of understanding by investors may be a potential barrier as well.

### Political institutions and regulatory frameworks

The international biomass, bioenergy, and biofuel market is in its infancy, with no clear trade agreements and a lack of consensus in international settings. Many countries have different import tariffs for biomass and additional duties and taxes on liquid biofuels. Consequently, most transactions take place between a few countries, and are based on bilateral agreements. In turn, this hinders a fair, competitive, and increasing business in bioenergy. From this perspective, biofuel quality standards are an important element. However, such standards are not yet available. Fortunately, the importance of international trade aspects for bioenergy-related products is recognized by international organizations (e.g., EC, World Trade Organization). As a result, existing policies, fiscal frameworks, and (agricultural) schemes are currently reconsidered, with the intention to stimulate and open up international trade in these products. Obviously, conflicting policies as indicated in the previous section will be reconsidered and addressed too.

Compared to for instance Germany and Sweden, biofuel policies in the Netherlands have been very unstable the past ten years (Thuijl & Deurwaarder 2006). In addition, economic support is only provided to R&D projects focused on second-generation biofuel. Moreover, any financial compensation for the commercial use of biofuels is absent. Consequently, national biofuel prices for end-consumers are considerable higher than petroleum fuels.

In Europe as elsewhere, new vehicles are sold with warranties. Warranties are invalidated if unapproved fuels are used. To date, only few car manufacturers have approved the use of biodiesel and low blends with some models. Obviously, biofuel quality standards have to be in place before such warranties can be provided, in turn, absence of official car manufacturers' approval delays large-scale market introduction of biofuels significantly.

### Market demand

Diffusion of biofuels does not depend on technological advances and favorable economic conditions alone. Availability and familiarity too are primary elements by which many end-consumers judge biofuels' value. In the Netherlands both, the availability and familiarity of biofuels as road transportation fuel are low. Hence, and consistent with economic theories of adoption and diffusion, Dutch consumers are generally hesitant to use biofuels, which results in a poor demand from the

market site. The higher price of biofuels adds up to this attitude. A good understanding and acceptance of biofuels by the wider public are perceived essential, to stimulate market demand and to encourage policies supporting the introduction and wider use of it. From this perspective, additional biofuel demand can be created by public information campaigns and policy measures. A recent example of such measure that has been put into practice by the Dutch government is the obligation for fuel suppliers to sell at least 2% biofuels of their annual total fuel sales. This amount will be gradually increased to 5.75% by 2010, and follows then the targets of the EU Biofuel Directive. Obviously, this policy measure provides a steady growth in biofuel demand at the national level.

#### Cultural and public perception

In essence, the answer to this sub-section is discussed in the previous section by arguing that fuels other than gasoline might be not accepted by some, since it is in discordance with perceptions of what driving is about, and by what means that should be done. In addition to this, one might state that people who are not familiar with the opportunities and benefits from the use of biofuels, and who have only little knowledge about biomass conversion technologies, tend to have prejudices that may be ungrounded. Often these people have had, or have heard about, negative experiences, which are translated into a too critical attitude against biofuels. Negative publicity or unexpected events can reinforce this attitude. For instance, recently a biomass-to-energy power plant exploded in the south of the Netherlands. As a result, a stream of censorious articles and interviews popped up in daily papers and other media sources. Obviously, such event shapes a rather negative public perception about biofuels.

#### Objectionable societal and environmental effects

Although great expectations exist about the application of bioenergy and biofuels, large-scale utilization comes together with potential high risks in other domains that cannot be ignored. First, production of biofuels from energy crops requires land and can drive the production of food crops away, which may translate into unenthusiastic public attitudes against biofuels. Furthermore, one might think about environmental and ecological issues (e.g., potential loss of biodiversity, soil erosion, freshwater use, nutrient leaching, pollution from fertilizers), and adverse economical and social effects (e.g., quality of employment, use of child labor, health effects). In order to address these potential significant negative side-effects, the bioenergy and biofuel sector must rely on sustainable (in the broadest sense) production of biomass for energy which ensures minimum social and ecological standards. In addition, these concerns might turn into a driver for the development of second-generation biofuels which, per definition, not compete with the food sector.

### **3.3.3 Concluding words**

In line with the findings from the previous research question, especially non-technical rather than pure technical barriers obstruct an accelerated development and large-scale market introduction of biofuels. Furthermore, the barriers for bioenergy and biofuels are dynamic, involve a large range of stakeholders, and depend on the (regional) context. Nevertheless, it seems that strategies and interventions are available to overcome the majority of the indicated barrier. Table 4 briefly summarizes the findings presented in this section.

**Table 4: Important factors impeding large-scale commercialization of biofuels in the Netherlands**

<b>Factor</b>	<b>Description</b>
Technological hurdles	Considerable technological difficulties with promising second-generation biofuels Desired pre-treatment densification technologies first in its early R&D stages Technical compatibility issues with some vehicles <5-10% ethanol blends Limited offer of the necessary flexible fuel technology for >5-10% ethanol blends Storage issues with biodiesel since it degrades little faster than petroleum diesel
Supply, distribution infrastructures and maintenance networks	Uncertainties about potential land and energy-crop feedstock availability Often required distant transport over road/rail reduces the overall benefits of biofuels Costly adaptation of existing fuel station equipment necessary for >5-10% blends
Competency issues	Promotion of fossil-based 'environmentally friendly' products by oil companies Lack of knowledge, skills, and institutional capacity (also by investors)
Political institutions and regulatory frameworks	Conflicting (environmental) regulations at different levels Lack of international agreed standards, certification systems, and trade schemes
Market demand	Low biofuel understanding/familiarity/acceptance by end-consumers, and high prices creates hesitance to use biofuels
Cultural and public perception	Existing prejudices (e.g., through perception, prior negative experiences, unexpected events) may shape critical and negative attitudes against biofuels by parts of the community
Objectionable societal and environmental effects	Biomass production from energy-crops raises questions about competition with food-crops, biodiversity, soil erosion, freshwater use, nutrient leaching, pollution from fertilizers, economical and social side-effects, etc.

## **4 Transitions towards sustainability**

### **4.1 Introduction**

#### ***4.1.1 Aims and structure of this chapter***

This chapter focuses on the topic of change mechanisms towards sustainable systems in society. One of the approaches aimed at achieving sustainability suggests that an encompassing set of transformations and changes are needed. Analysts from different disciplinary backgrounds refer to this by using a variety of concepts. Some well-known include system innovation, technological regime shifts, industrial transformation, technological transition, systematic innovations, socio-economic paradigm shift (Kemp 1994; Elzen & Wieczorek 2005). In this chapter, all these are embraced under the label transition. Accordingly, the chapter's main aim is to explore the rather theoretical and conceptual train of thoughts about transitions and the route towards a more sustainable road mobility system. By doing so, research question 3 can be addressed.

First, a historical transition example is discussed briefly to better understand the examination about some general issues that come along in alterations of complex societal systems. Subsequently, this discussion makes it possible to elaborate on common acknowledged transition characteristics, after which the focus is directed towards a policy approach that aims to induce sustainability transitions, i.e., a transition management system. The chapter closes with a discussion of research question 3, by evaluating transition theory and the management system, and how it conceptually deals with impeding factors as discussed in the previous chapter. Furthermore, two different market introduction strategies for alternative, more sustainable technologies are discussed that can be applied (in combination), to induce the transition process. Finally, these findings are translated into conceptual strategic directions for the potential biofuel sector.

#### ***4.1.2 Method of approach***

The discussions and findings presented in this chapter are mainly based on scientific articles, dissertations, and policy papers in the field of transition theories. The intention is to highlight the discipline's background and its relevance, and to explain some important viewpoints. In order to stay as objective as possible, some criticisms from other scientific disciplines are also presented.

### **4.2 Understanding transitions**

#### ***4.2.1 An introductory***

The historical transition example presented below in box 14 stems from a detailed case-study elaborated in Geels (2002). The description is a simplistic version which merely sketches some vital developments that influenced the transition process from horse-and-carriages to automobiles (1860-1930).



From 1860 onwards, the utilization of horses-and-carriages as urban transportation mean increased significantly. Cities grew, and the amount and distance of travel increased. As a result, different line-ups emerged: among others, private carriages, horse-carriage omnibuses, and inflexible horse-trams (horse-drawn carriages on railroads) providing inner city public transportation services. To protect this system, stable-boys, black-smiths and fertilizers produced by farmers ‘maintained’ the animals. Additionally, large stables were built to accommodate horses. New markets emerged and employed thousands of people in carriage-manufacturing business. Regulations were issued to prevent sickness and stimulate proper care for horses. In sum, “an entire regime was created around horse-based transportation, involving many social groups” (Geels 2002: p.250). Expansion of this transportation regime progressed until the end of the 19th century. By 1930 this regime looked very different. What happened?

The briefest epigrammatic answer to this question: a transition took place. A multifarious (often interrelated) set of developments and conditions opened up the automobile market. For example, the use of horses for transportation became more expensive (e.g., horse feeding and stabling, congestion). Additionally, due to safety and street-hygiene issues horses acquired a negative public image (Mom 1997). On the other hand, (radical) technological innovations (e.g., steel bodies, propulsion systems) resulting from industrialization, funded road and fuel supply infrastructures, and traffic rules, stimulated the use of automobiles heavily. Public support was gained due to improved overall convenience, and they were seen as the transportation mean for the future. Additionally, on a higher level, a new consumer culture, ideology, and rise of capitalism and (sub-)urbanization indirectly energized the substitution process. Analogous to the horse-and-carriages regime, the automobile regime consists of many related markets and socio-economic activities such as, car manufacturing, service stations, and recreational practices. And the sum of these keeps the regime stable and ‘alive’. Geels (2002: p.251 & 252) concludes that “urban passenger transportation in 1930 was very different from 1860. New technologies were used. New infrastructures had been created, and new traffic rules, and new mobility practices (e.g., touring). The symbolic perception of the role of the street had changed from social meeting place to transport artery. New functionalities had been introduced.” Figure 10 roughly visualizes this transition process by presenting the amount of road horses and cars against time in the United States.

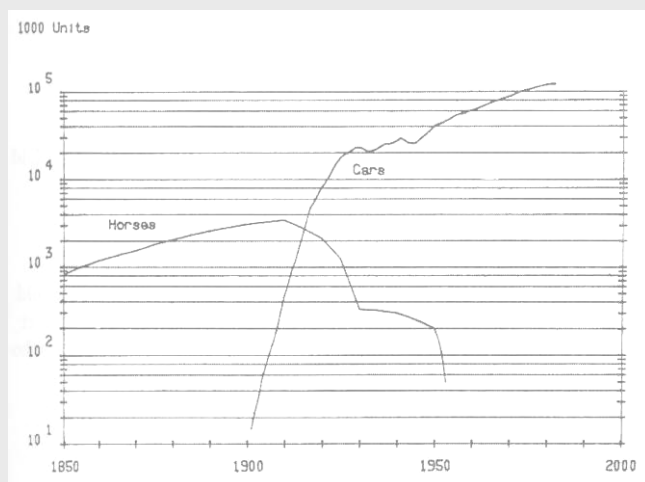


Figure 10: Population of road horses and number of cars in US (Nakicenovic 1986: p.320 from Geels 2002: p.39)

**Box 14: Transition example: From horse-and-carriages to automobiles (1860-1930)**

Other appealing examples of transitions are: (1) the changeover from coal to natural gas as important energy carrier in the Netherlands in the 1950s and 1960s (Verbong 2000 from Rotmans 2005), (2) the replacements of piston aircraft to jetliners from 1926 to 1975 (Geels 2002), and (3) the upheaval from sailing ships to steamships for oceanic transport from 1780 to 1920 (Drift 2006). In general one might

state that transitions take place from time to time in every part of society. Additionally, changes come typically in fits and starts, and a complete system alteration lasts at least one to two generations (i.e., 25-50 years) (Drift 2006). Furthermore, in a transition, technological as well as social and cultural dimensions of such system change drastically (Elzen & Wieczorek 2005). The examples and explanation affirms the transition's broad complexity. Box 15 provides a rather brief definition of a transition.

A transition refers to a long-term process of sweeping changes in an encompassing system that serves a fundamental societal function (e.g., transportation, energy supply, communication, health care) and these changes alter the overall structure of such system drastically.

**Box 15: Definition of a transition**

Prior to the discussion of common-accepted and more specific characteristics of transitions, some theoretical background from different perspectives on (evolutionary) change processes and regimes, substitution, and co-evolution processes is necessary:

Evolution theories and technological change

The transition examples in the previous sub-section demonstrate that the emergence and evolution (i.e., the evolution) of technological systems (e.g., a propulsion system) act as key factor in transition processes. Also in sustainability transitions “technological change has been defined as crucial” (Elzen & Wieczorek 2005: p.653). Abundant examples of persistent patterns and trends in technical change support that these processes are not chaotic but proceed in certain directions, something which is widely recognized (Kemp 1994). Nevertheless, there is an ongoing global debate about the nature of technological evolution (e.g., Ziman 2000).

Evolutionary theories often emphasize the structured nature of technological change. As Raven (2005) explains, the economist Schumpeter was the first to mention evolutionary aspects in economic processes and technological change. Technology was relevant since it affected the firm's profitability, and in order to understand economic growth, he built upon Darwinian concepts of variation and selection and related them to technological change (Geels 2002). In this view, variation is not random but pre-structured by regimes or paradigms, and shifts in selection environments lead to co-evolution of technology, industry structure, and supporting institutions (Whyte 2007). Finally, Schumpeter's view was that expansion cannot explain expansion, and a self exciting system needs a stimulus and that stimulus comes from new combinations (Metcalf 2007). Technological change is such process of new combinations. In contrast, Lamarck had proposed a mechanism for evolution based on the inheritance of characteristics acquired during lifetime (e.g., passing on of learned knowledge or well-exercised muscles) through processes of learning (Lamarck 1809 from Whyte 2007). Despite the fact that both, Darwinian and Lamarckian concepts may provide a useful theoretical lens for understanding longer-term changes, each has strong limitations in its applicability.<sup>35</sup> This indistinctness justifies considering transitions from an alternative perspective.

---

<sup>35</sup> Further elaboration on evolution theories falls beyond the report's scope. Interesting insights can be found in Metcalfe (2007) and Whyte (2007).

### Innovation forms and regimes of stability

Much modern work from economists, historians and more recently sociologists have studied regularities in technological change and have come up with concepts to account for the ordering and structuring of technology (Kemp 1994). To start clarifying the notion of transitions from a theoretical angle, an exploration of established innovation literature reports broadly about the distinction between incremental and radical forms of innovations. The majority of innovations brought to the market can be characterized as incremental, which means that they build further upon existing technologies, often offering relative little improvement in terms of functionality and performance, and can be embedded in existing environments with diminutive adaptation from users, etc. The development-path of such innovation is often referred to as technological trajectory (Dosi 1982). On the other hand, radical innovations less often break through to markets for several reasons. In general, they call for substantial development investments in terms of knowledge and capital. Additionally, they face huge resistance because significant adjustments of existing situations and practices (e.g., infrastructure, user routines) are required. Basically, the set of factors impeding breakthrough are discussed in Q2A.

Referring back to the transition example, both forms of innovation can be demonstrated. Within the regime (or system<sup>36</sup>) of transportation via horses and carriages, many incremental (technological) changes improved overall accessibility and functionality (e.g., the development of different modes and carriages). In this more or less stable regime, the ‘technological’ transportation principle of horses and carriages dominated, and affected social life. Smith, Stirling & Berkhout (2005: p.1508) conclude that “regimes, by definition, have a tendency to exclude options and thereby introduce stability.” Regimes delineate a set of ‘rules and boundaries’ that guide but do not fix the kind of research activities. As a result, incremental innovations prevail within a certain socio-technical regime due to interdependency and little freedom of action. In addition, the restricted (focused) nature of change accounts mainly by the embedding of existing technologies, (engineering) practices and routines, cultural beliefs values, etc., and this rigid embedding creates economic, technological, cognitive and social barriers for breakthrough of new technologies (Kemp et al. 1998). Box 16 provides a definition of a socio-technical regime by Rip & Kemp (1998) and Geels (2002) from Smith et al. (2005: p.1493).

Socio-technical regimes are relatively stable configurations of institutions, techniques and artifacts, as well as rules, practices and networks that determine the ‘normal’ development and use of technologies. Furthermore, Regimes fulfill socially valued functions, which they also help to constitute.

#### **Box 16: Definition of a socio-technical regime**

Despite their relative stable nature, regimes change. Hence, the concept of regimes forms a central topic of interest in the discipline of transition theory and its literature. The shift from one stable socio-technical regime to another refers to a transition and is usually an outcome of a series of new combinations and (technical) innovations. Obviously, in the transportation example this happened by the substitution of horses and carriages for transportation by automobiles.

---

<sup>36</sup> In literature, both concepts are used to indicate more or less the same. The term ‘regime’ is preferred because most studies using the latter and emphasize especially technical characteristics.

### Co-evolution and inter-artifactual competition

Although it might seem a logical process and perhaps a simple ‘victory’ for the automobile with internal combustion engine today, at that time, multifarious innovative transportation technologies and user-functions emerged (e.g., electric and steam powered automobiles, the electric tram, bicycle). These competed not only with each other but also with the established regime. Dominance of ICE automobiles was not at all clearly perceptible at the beginning of the 20<sup>th</sup> century. This emphasizes the significant transition aspects of co-evolution on the level of technology and user-functions, and inter-competition. In case-studies about technical change in the evolution of automobiles and road building techniques, Mom (2003 & 2004: p.88) demonstrates that complex interactions take place between competing technologies and that the alternatives constantly adapt in order to stay in the race. “They do so, by ‘stealing’ each other’s properties and functions in such a way that a constant flow of these properties and functions between the competing technologies is kept in motion.” As a result, the individual technologies over time mitigate disadvantages, and advance their (technical) properties and introduce user functionality improvements. An important conclusion is that the ‘winning’ or dominant technology ultimately is not a victory of one, but a combination (hybrid-form) of functionalities and relevant properties of all competing alternatives. The mechanism which describes the flow (stealing) of these functions and properties in the direction of a universal, multi-functional technology is called the Pluto effect<sup>37</sup> (Mom 2004). From this perspective, one must treat the concept of technology substitution from one by another with care, since absolute, clear-cut substitution seems rather the exception than the rule when alternative technologies are at stake.

#### **4.2.2 Transition characteristics**

The historical example and theoretical background about transitions in the previous sub-sections provides a good starting point to understand the general acknowledged transition characteristics.<sup>38</sup> This discussion is necessary since transition management perspectives (starting point for addressing research question 3) take into account these characteristics.

The first characteristic of a transition is that they are defined to occur in encompassing systems in relation to basic human needs. These systems are relatively stable, fulfill a societal function which makes them context specific (e.g., mobility, fresh water supply), and are characterized by a range of technologies, infrastructures, patterns of behavior, cultural values, policies, etc.

The second characteristic stems from the theoretical discussion above about technological change, (system-)innovations, and co-evolution processes within transitions, i.e., transitions imply long-term, complex, uncertain change processes that affect all, or a large part of the dimensions mentioned in the first characteristic. Furthermore, they are at least characterized by a combination of technical and societal/behavioral change, also described as a process of co-evolution and inter-artifactual competition.

The third characteristic is that transitions involve a wide variety of different actors (multi-actor), including governmental bodies, industry and other NGOs, research organizations, and society.

---

<sup>37</sup> “Metaphorically the engineer of the existing technology stands on a cart with a sausage in his hand (e.g. possible market shares). Pluto (the engineers of the new technology) runs after the sausage, but in doing so also pulls forward the cart (existing technology) (Geels 2002: p.349).

<sup>38</sup> The presented transition characteristics are based on descriptions in Elzen & Wieczorek (2005), Drift (2006), and Rotmans (2005).

Furthermore, they are a result of many enforcing factors that influence each other (multi-factor) and result in a combination of technical, regulatory, societal, and behavioral change. Finally, these changes take place at various levels (multi-level), i.e., the micro-, meso-, and macro-level as discussed before.

### 4.3 Inducing sustainability transitions in practice

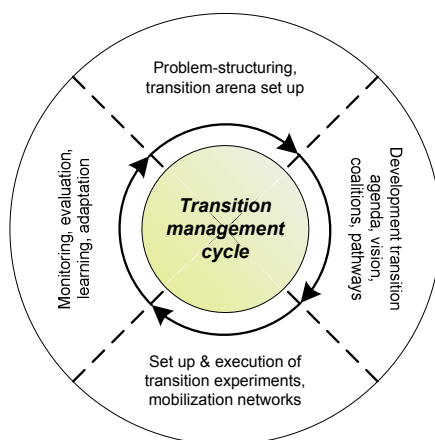
#### 4.3.1 Transition management

In the past many transitions have taken place. However, they have not always led to structural socio-economic and ecological improvements. In order to increase the probability that a transition ‘moves’ towards a more sustainable society, steering at the highest level is necessary. Based on this philosophy, a transition management framework is put on the political agenda in the Netherlands to shape its policy towards sustainability (van de Kerkhof & Wieczorek 2005). At first sight, this approach might be associated with top-down supervision and control. This is however a misinterpretation since transition management beholds complexity and uncertainty as point of departure. Moreover, the approach acknowledges the restricted and limited degree of steering the societal dynamics (Rotmans 2005), and should therefore involve a continuous interaction between bottom-up idea-generation and elaboration, and top-down vision development and implementation (VROMraad 2004). Table 5 summarizes the guiding principles and rationale behind the introduction of the transition management approach, the rules of thumb for steering, and the preconditions for successful deployment.

**Table 5: Transition management as policy approach: guiding principles, rationale, steering, and preconditions for successful deployment (freely translated)**

<b>Guiding principles and rationale behind transition management as policy approach (Rotmans 2005)</b>	<b>Rules of thumb for steering (Rotmans, Kemp &amp; van Asselt 2001 from Rotmans 2005)</b>	<b>Preconditions (VROMraad 2004)</b>
Changes in society proceed whimsically and strongly non-linear, and encompass surprises and discontinuities per definition	Integral policy (multi-factor) Multi-actor approach	A broad sense of urgency Leadership
Complexity and uncertainty are no problem of the obstacle, but points of departure for steering societal change	Multi-level coordination Use long-term considerations as framework for short-term actions	Commitment for the approach Willingness to make the necessary cultural turn
Steering societal change is a reflexive process of seeking, learning and experimenting	Steering on learning processes and experimenting	An active government in different roles
Everybody steers from the awareness of the possibilities on the one hand, but also from the restrictions and limitations on the other hand	Stay open during a long time for a range of options within the defined direction	A careful long-term direction/orchestration
Society is not fully, but partially and in parts makable		Trust relationships between the participating actors
Supervision and control of societal change processes is an illusion, the highest possible to achieve is coordination and the influence on that		Willingness to invest in energy transitions

Obviously, it is a challenge to translate these relatively abstract notions into a practical useable steering framework. Transition scholars attempted to address this challenge and developed the transition management cycle to stress the approach's cyclical process of developing-rounds on different levels. The transition management cycle includes several important activities to initiate and stimulate transitions toward sustainability (Drift 2006). More specifically, four elements can be distinguished, i.e., (1) problem-structuring and the set up of a transition arena, (2) the development of a transition agenda, sustainability vision and, deduced from that, transition pathways, (3) the set up and execution of transition experiments and the mobilization of the emerged transition networks, and (4) the monitoring of, and evaluation/learning from the transition experiments with the intention to adapt visions, agendas and coalitions (Loorbach 2002; Loorbach & Rotmans 2005 from Rotmans 2005). Worth mentioning is the fact that this cycle must be gone through many times. Figure 11 portrays the transition management cycle.



**Figure 11: The cycle of transition management (source of design: Rotmans 2005 p.53)**

Although it might look like the four elements follow up each other in sequence, in practice the activities are also executed in parallel and even in a mixed way. Below, a brief explanation of each element<sup>39</sup> in the transition management cycle is given.<sup>40</sup>

### Arenas

Transition management calls for an active commitment from governmental bodies, industries and other NGOs, research organizations, society, among others. Obviously, these parties have their own ideas and visions about the future. However, achieving societal changes towards sustainability requires common and long-term visions. In order to develop such sustainability visions, the first step in the cycle is the organization of a transition arena, i.e., a network around a specific transition issue. Speaking in terms of the report's context one might think about the transition from fossil-based fuels to renewables-based fuels for road transportation purposes (e.g., biofuels).

In the transition arena, innovative frontrunners (e.g., SMEs<sup>41</sup>, entrepreneurs, visionaries) are brought together with decision makers and influential institutions, with the intention to confront the different problem perceptions and solution directions. The aim is to develop a common understanding

<sup>39</sup> A more elaborated explanation of the elements can be found in Rotmans (2005).

<sup>40</sup> These summarized descriptions are partially based on Drift (2006) and Kemp & van den Bosch (2006).

<sup>41</sup> SMEs is an acronym for small- and medium-sized enterprises.

of the problem and a long-term sustainability vision, and the explicit transition activities. According to Rotmans (2005), the frontrunners in this context must be able to cogitate jointly about complex (cross-sector) problems, willing to renew, and being amenable for novel solutions.

### Agenda

In the second element, the long-term sustainability visions are translated to clear mid-long steps by coalitions between private and public organizations who are closely involved with the problem. Together they formulate plans and put the means at disposal to realize the projects necessary that lead towards a sustainable future.

The arena-participants are expected to convince interested parties within their own network of the importance to be involved in the development of mid-term plans and projects for a specific region or sector (e.g., a biofuel sector). As a result, coalitions of stakeholders emerge that are stimulated to formulate transition pathways (e.g., biomass-to-bioenergy, hydrogen, electricity) leading towards the long-term sustainability visions as proposed in the previous step. The plans and projects together with the means to realize them are called the transition agenda. The development of such agenda requires persuasiveness and leadership, sense of urgency, a connection between current interests and future visions, and stakeholder-commitment in a given region or sector.

### Experiments and learning

After the development of the sustainability visions and transition pathways, an image is shaped about the possible directions for societal change and renewal. However, uncertainty still exists about the exact solution for the problem. To address this uncertainty, experiments in practice are necessary to learn about different (innovative) solutions and their (societal) impact, and to strengthen the stakeholders' coalition.

More specifically, transition experiments are carried out in practice and involve high risks (success rate-wise), but may contribute to the transition to a large extent. In such experiment much is learned about changes on technical, social, environmental, and economical dimensions. The experiments vary in size, i.e., from small-scale feasibility checks to large-scale international demonstration experiments like the BEST project. Nonetheless, all experiments have to fit within the developed visions, aims and transition pathways, and embrace the following characteristics: (1) exploration of solutions to persistent problems, (2) aimed at learning about different aspects, (3) bringing together private and public (research) organizations, and (4) may possibly contribute to system renewal and thus the transition process.

As discussed, the high level of risk reduces inherently the probability of success. However, a successful experiment is one in which much is learned. It is therefore essential to formulate exact objectives at forehand. Furthermore, a constant process of evaluation and monitoring throughout the experiment is required at all times.

#### ***4.3.2 Transition management: the itinerary towards sustainable road mobility?***

Although the transition management system as a policy framework seems conceivable for inducing sustainable energy transitions, critical comments are also found in scientific literature. First of all, according to Hisschemöller, Bode & van de Kerkhof (2006: p.1227), "there is a lack of integrated knowledge on the transition to a sustainable energy system." The authors state that technologists,

economists, and political scientists barely interact with respect to their disciplinary insights about the energy transition issue. For instance, for those who work in the field of adoption and diffusion of innovations, the idea that viable technologies conquer the market at large-scale by virtue of their advantages may seem naïve. This consideration is in line with findings by Mom who argues that victory of one technology is mostly not the case. Instead it involves a process of hybridization between alternatives that explains the ‘winning’ of one technology over all others (Mom 2004). Furthermore, van de Kerkhof & Wieczorek (2005) point out that criticisms are found about the transition management ideas of steering and coordinating as instrument for ‘unmanageable’ and complex processes as social change. Finally, it is difficult to validate and translate the transition management principles into general applicable guidelines, since the system is partially based on expectations and limited insights from context-specific past transitions. As a result, nobody knows the exact preconditions for a successful transition management.

Nevertheless, transition management earns support since it links longer-term visions about environmental, economic, societal, and political issues, and relates them to local short-term actions. Additionally, it tries to involve relevant stakeholders in arenas to create shared visions, and stimulates an open dialogue on plausible pathways and solutions to persistent environmental problems. Finally, transition management is the only integrated management proposal for governments to deal with the complexity of transitions aimed at sustainability. From this perspective and in an attempt to answer the sub-section’s title question, the following conclusion can be drawn:

Transition management as policy framework shapes, at least in theory, favorable (and perhaps necessary) conditions for inducing transitions aimed at a sustainable society. Additionally, it offers some general insights about the preconditions to initiate such transitions (see table 5), also in light of the road mobility system. On the other hand, the transition management approach is not specific enough to provide sufficient and clear strategic directions for managing innovations at the (lower) sector- and operations-level. As a result, the previously discussed factors that (1) impede the transition process towards a sustainable road mobility system and (2) create large-scale commercialization barriers for more sustainable road transportation technologies can not be addressed directly. Hence, solutions to overcome the introduction barriers should be searched for elsewhere.

**Box 17: Conclusion about transition management with respect to sustainable road mobility**

***4.3.3 Transition strategies: towards sustainable road mobility***

Now that the theoretical train of thoughts about transitions and the transition management system is discussed more in-depth, a better understanding of more specific strategies can be presented that deal with the complex transition process towards a more sustainable road mobility system.

It has become clear that it is still difficult to identify operational-level introduction strategies for new, sustainable technologies, innovations, or other practices. As a result, transition scholars elaborated on two general strategies that can be distinguished when it comes to attempts to induce transitions, i.e., niche accumulation and hybridization (Geels 2005). In niche accumulation, innovations start as a radical distinctions from the current regime (in terms of technology, market, institutional arrangements, etc.) and involves smart experimentations in niche markets. Innovations in



hybridization, start close to the existing regime and aim to diverge over time towards a more desirable design (Raven 2007). Both strategies are discussed below.<sup>42</sup>

#### Niche accumulation

The application of a technology in different niche markets refers to niche accumulation. The aim is to make the technology/market combination more robust. Initially, the new technology or innovation is introduced as a radical deviation from the existing dominant design or practice. This can be done since the niche market ‘protects’ the innovation by for instance tax exemptions or other (financial) beneficinations. A second step in the niche accumulation strategy is that the innovation moves to other niche markets (i.e., niche branching), which improves the fit between the technology and different markets, and increases the credibility of the innovation in general. Finally, when enough internal momentum is ‘gathered’ and the innovation is embedded in societal systems, a new regime may emerge on mainstream markets. The rationale for applying a niche accumulation strategy is that it opens great opportunities for learning about technology/market combinations. Together with this strategy, a risk emerges since the innovation may continue to exist only in small-scale niche applications.

Patterns of niche accumulation abound in literature. For instance, experiments with fuel cell technology have taken place in a variety of niche markets since the 1960s. The early applications started in favor of space traveling and the US army and navy. Afterwards, research focused on small- and large-scale decentralized electricity production, to date fuel cell technology is explored for public and private vehicle propulsion (Hendry, Harborne & Brown 2006). All these markets differ much and require specific characteristics from the fuel cell technology. In the mean time, the technology is more and more accepted in the societal system which may eventually lead to significant stable regimes around the fuel cell technology in different markets.

#### Hybridization

The second major strategy to induce sustainability transitions revolves around hybridization. Hybridization refers to the process where a new technology hooks on an existing (mostly dominant) technology to form a hybrid, more desirable type. This can be done when for instance a specific problem with the dominant design must be solved. In these cases, a so-called add-on element (a novel technology/innovation) may be introduced in the mainstream market. Referring back to the transition example about horse-and-carriages to automobiles, the automobile was firstly promoted as horseless carriage in which engines were mounted on the carriages as add-on, auxiliary elements. Initially, these carriages drove over the same pavements (infrastructure) and used the existing design of carriages, clearly an application of a new technology in an existing regime. A similar, more recent example of hybridization might be seen in the case of electric vehicles. To date, HEVs possess an electric engine/generator as add-on device for the ICE to attain higher fuel efficiency. The electric engines in these HEVs are not dependent on externally acquired electric power, and thus circumvent the disadvantage of full electric vehicles’ limited range due to the unavailability of an electric power infrastructure. However, when the number of HEVs increases it might become interesting to build such infrastructure. Obviously, the hybridization strategy involves a co-evolution process between

---

<sup>42</sup> The elaboration partially stems from an article by Raven (2007) about both strategies.

alternative technologies, and is also in accordance with Mom’s inter-artifactual ‘competition’ between technologies.

The rationale to apply a hybridization strategy is that a promising small-scale technology can avoid fierce competition from established, dominant designs. Especially in those cases where rigid infrastructures are crucial aspects within a regime, the hybridization strategy can be helpful in favor of novelties. Thus, by creating hybrid technologies the fit between innovation and existing practices/infrastructures is improved. The ultimate challenges are then to increase the innovation’s significance, and to reach a more desirable and widely diffused design. This challenge, however, demystifies a pitfall since the innovation may remain in the existing regime without causing a significant transformation. Table 6 portrays the main differences between both strategies.

**Table 6: Differences between niche accumulation and hybridization (Raven 2007: p.2392)**

	<b>Niche accumulation</b>	<b>Hybridization</b>
Description	Radical innovation improves and stabilizes in multiple niche markets until it can invade mainstream market	Innovation starts close to existing regime, but lures mainstream actors into pursuing alternative trajectory
Type of innovation	Radically different from regime technology	Add-on to regime technology
Market focus	Niche markets	Mainstream markets
Niche-regime relationship	Competitive	Symbiotic
Driving actor	Small innovative firms (or other regime outsiders like NGO)	Incumbent firms (+outsiders?)
Main rationale	Great potential for learning about new market/technology combinations	Easy integration in existing regime (infrastructure)
Pitfalls	Dividing resources across technology/market combinations can result in insufficient momentum for any of the combinations; Exchanging lessons between combinations can be difficult; Danger of remaining stuck in small market niches	Danger of getting stuck into existing regime without radical transformation; Regime optimization hardens competition for other alternatives

### Choosing between the two strategies

This sub-section assessed the differences between niche accumulation and hybridization as innovation introduction strategy to induce transition processes towards sustainability. These strategies are each others theoretical extremes and applied, often unintentionally, throughout history to overcome resistance by stable regimes against fundamental change. In practice, any transition strategy involves a combination of both. For example, an innovation can start according to the process of niche accumulation, in which different niche markets are explored. Later on, the more mature innovation may from hybrid combinations with a dominant design and enter mainstream markets. As a result, the patterns in both strategies are also relevant during the route towards a sustainable road mobility system. It is however essential to recognize the potential pitfalls since they can impede the transition process significantly. Finally, as Raven (2007) explains, the most important notion is that insights in the innovation’s history and the innovation context are crucial in determining what approach is appropriate as introduction strategy. Obviously, this accounts to in an attempt to cope with barriers for

new, environmentally benign road transportation technologies and innovations. This conclusion emphasizes the value of the discussion about biofuels' characteristics and past experiences in the next chapter. As a result, more deliberate directions can be provided in favor of the framework with recommendations for the biofuel value-chain.

## **4.4 Discussion of research question 3**

### **4.4.1 Introduction**

Research question 3 reads: “what conceptual strategic directions, from a transition theory point of view, lower barriers as discussed in Q2A and Q2B, and stimulate the desired transition process?” The question’s rationale is to investigate how transition theories and the transition management system attempt to initiate and stimulate transitions towards sustainability, and how this can be translated into conceptual directions and suggestions with respect to the framework with recommendations for the biofuel value-chain later on.

### **4.4.2 Elaboration Q3**

According to the ideas behind transition (management) theory, several general principles and guidelines can be indicated that deal with obstructing factors for sustainable road transportation technologies. First, a delegation of actors from different (societal) sectors is required, which form the transition arena around the theme of sustainable road mobility. As a result, stakeholders from dominant and related sectors (e.g., oil companies, car manufacturers) should be brought together with governmental bodies, entrepreneurs (e.g., biofuel producers), societal groups, and research institutions. In that network, discussions about the specific transition issue should lead to a common agreed long-term sustainability vision and an identification of nearer-term transition pathways that lead towards the vision. In such arena, special attention must be directed to non-technical factors (e.g., regulations, market demand issues) since they influence to a large extent the transition pace,<sup>43</sup> and can be addressed in broad consultation only.

Each transition pathway revolves around a sector (e.g., biofuels, fuel cells, alternative public transportation system) and involves relevant public and private organizations. This network is commissioned to promote, optimize, and enlarge the sector’s viability. Additionally, through experimenting there can be dealt with specific technological hurdles. As far as introduction strategy concerns, both, niche accumulation and hybridization must be applied in balance to maximize the probability of short- and long-term market success of promising sustainable road transportation technologies. Consequently, great opportunities for learning are opened due to ‘protected’ new technology/market combinations. Furthermore, easy entrance into stable, mainstream markets can be realized through add-on applications of alternative technologies. Table 7 translates the above presented conceptual strategic directions into suggestions with respect to the framework with recommendations for the potential biofuel value-chain.

---

<sup>43</sup> As concluded in chapter 3.

**Table 7: Conceptual strategic directions for inducing sustainability transitions and suggestions for the framework with recommendations for the biofuel value-chain**

Transition theory	Applied to the biofuel sector
Organization of the arena and the formulation of the sustainability transition issues and visions	Vision formulation: perceive biomass-to-biofuels as one of the relevant transition pathways that stimulates the transition towards a more sustainable road mobility system
Network building through involvement of relevant stakeholders from different sectors and levels (also from dominant regimes)	Coalition formation between biofuel-related stakeholders from dominant sectors (e.g., oil companies, car manufacturers), governmental bodies, entrepreneurs (e.g., biomass and biofuel producers), societal groups, and research institutions to reach consensus, alignment, and as facilitator for collaboration
Identification of different transition pathways, setting up of projects and experiments for learning based on longer-term considerations	By means of experiments and research projects: Identification of new market opportunities for biomass, bioenergy, biofuels, and its co-products to increase its total market value (niche accumulation)
Applications of both, the niche accumulation and hybridization strategy for market introduction of alternative, more sustainable technologies	Early mainstream market introduction of biofuels by means of ‘add-on’ applications which result in added-value for stakeholders from existing regimes and practices (hybridization)

#### **4.4.3 Concluding words**

The scientific discipline of transition theory conceptualizes long-term change processes in technology and society. Based on historical case-studies the theory is refined, and emphasizes the perspective that transitions are not driven by single factors or drivers, but come about through alignments of processes at different levels. Transition theory forms the basis for the transition management cycle; a recently introduced policy tool to facilitate and steer (energy) transition processes in the Netherlands. Vision alignment, commitment through sense of urgency, and collaboration between governmental bodies, industry partners, NGOs, and society are basic principles forming the cycle. Also with respect to bioenergy and biofuels, transition management ought to be able to induce an accelerated and lasting market introduction. From a theoretical point of view, this process should then be supported by the hybridization and niche accumulation strategies that principally facilitate a straightforward market introduction biofuels. The next chapter will discuss more in-depth how these conceptual strategies can be translated, and put into practice.



## **5 Part B: Biofuels and the value-chain**

### **5.1 Introduction**

#### ***5.1.1 Aims and structure of this chapter***

Throughout this chapter, the earlier discussed theoretical findings about sustainable road mobility and the transition towards such system are linked to practical insights about biofuels' past experiences, current (regional) market position, and future potential. As a result, the combination of both parts provides the basic ingredients for the framework with preliminary set up recommendations for a large-scale biofuel value-chain near Rotterdam. Since the focus of research questions 4 and 5 is primarily directed to biofuels, both questions are subsequently addressed in this chapter. Finally, the framework and the report's conclusions are presented in the following final chapter.

#### ***5.1.2 Method of approach***

The case-study about biofuels (app. A) provides a great share of basic background knowledge used in answering both questions. Hence, it is highly recommended to read that case-study carefully before continuing. Where necessary, additional literature is consulted.

### **5.2 Discussion of research question 4**

#### ***5.2.1 Introduction***

By considering the findings presented throughout the case-study, one might conclude that no significant reasons are found to be skeptical about biofuels' potential ability to (1) be exploited viably on a worldwide-scale in the medium- to long-term, and capture at least 30% of today's petroleum fuels' market share, (2) stimulate socio-economic development in developing and rural regions, (3) reduce the local and global environmental burden stemming from our current road mobility system, (4) better secure and diversify energy supply, and (5) lessen dependency on political unstable regions. The afore-mentioned beneficial characteristics are general motivations convincing governments over the world to perceive liquid biofuels as highly relevant. However, in order to provide more specific strategic advice for successful large-scale biofuel utilization, it is useful to draw lessons from (past) experiences over the world. This section deals with this expediency by answering research question 4, i.e., "what lessons can be learned from biofuels' past experiences, critical issues, and future prospects, in the interests of nearer-term strategic directions for large-scale application of biofuels?"

The following sub-section identifies eminent lessons and classifies them in four apparently key-aspects that come along at the route towards an enduring global deployment of biofuels. The complete set is based on the case-study. Hence, level of justification detail is narrowed. Although the case-study provides a great deal of information, from which more lessons can be drawn, the elaboration is recapped with lessons primarily relevant for the framework later on. Furthermore, where possible the lessons are entwined with previous research findings to validate the applicability of the transition theory part in a practical context. Finally, no explicit distinction is made between ethanol and biodiesel throughout the elaboration for clarity and limitation.

## **5.2.2 Elaboration Q4: Lessons about...**

### Biofuels' technological outlook

Low blend biofuels (5-10%) can reach mainstream markets easily through existing fuel distribution networks, and without expensive engine conversions. This represents the route with the lowest barriers and should be pursued from the short-term onwards. Independent fuelling stations have proven to be able providing biofuels to end-consumers without much hindrance. Additionally, at the same time this route makes the distribution of high blend biofuels (e.g., E85, B100) possible for early market niches like FFVs and neat biodiesel-compatible vehicles. As a result, both the hybridization and niche accumulation introduction strategy is applicable. Hybridization refers then to the low blends in which the biofuel fraction acts as 'add-on' element in conventional petroleum fuels, and interacts (even literally) with dominant petroleum fuels, technologies, and practices from established infrastructures and networks. Consequently, a better performing, more sustainable 'hybrid' product becomes accessible in a straightforward way. The application of high blends represents the biofuels' niche accumulation strategy. However, these fuels are mostly incompatible in existing networks and with current technologies. Sufficient momentum can be reached by mobilizing captive (e.g., governmental) fleets equipped with adapted engines running on high blends marketed by for instance the independent fuelling stations. In this way, a market is created which is a means to overcome the earlier identified chicken-and-egg dilemma (no demand, then no supply, thus no demand). Additionally, evaluation of these 'leading by example fleets' enables great opportunities for learning about the market/technology combination, which in turn gives rise to the transition management principle of learning processes by experimenting (table 5). Moreover, bringing both strategies into action in the short-term raises immediately the essential information exchange and awareness by public and established industries. This results in positive loops, which may ultimately initiate the desired 'leaking out of innovations with niche functions' into the regime of road transportation fuels. Consequently, the high blend biofuels, related drivetrain technologies, and its infrastructural networks are then able to form stable systems on their own.

A second important lesson is that the co-products released, and the processing scale can improve the economic outlook (compared to petroleum fuels) of biofuels significantly. As a result, both aspects should be considered carefully when creating a biofuel value-chain. The co-products (e.g., glycerin, heat, electricity, animal feed, bioplastics, sweeteners) can be used as raw material in a variety of other sectors. However, since the economic value of some co-products may strongly vary, an ongoing search to innovative applications of these is necessary in order to reduce the cost-variation risk. The use of biofuels' co-products follows the hybridization path (in case of existing markets) or niche accumulation path (in case of novel applications in market niches).

On account of the rapid pace of technology development and investments in innovative biofuel projects, it is likely that a technological transition takes place in the domain of liquid biofuels. In this transition (which remarkably occurs within the complex road mobility transition), 'traditional' first-generation biofuels will, in all probability, be replaced gradually by second-generation biofuels (e.g., lignocellulosic feedstocks, forestry and industrial waste streams) with substantial benefits for the long-term. Although uncertain how exactly, both first- and second-generation types of biofuels may interact with each other over time, and in line with the Pluto effect. As a result, R&D investments should continue in these 'not yet significant' second-generation biofuels. Especially small innovative

firms, entrepreneurs, and research organizations have a substantial role in this long-term development trajectory. Glancing even beyond the application of second-generation biofuels as road transportation fuel, these biofuels can be used for hydrogen production in a very attractive (even with net negative emissions if combined with carbon sequestration) manner. In turn, interacting mechanisms are expected to show up again between these different applications of biofuels.

Referring back to transition theory, the technical lessons presented above are in reference with the previously discussed ‘transition steering rules of thumb’ by relying on (1) a multi-actor approach, (2) the use of long-term considerations for short-term actions, and (3) the necessity to stay open during a long time for a range of options within the defined direction (table 5). In sum, the technological outlook for biofuels in the short- and long-term appears reconcilable with transition management principles.

#### Political commitment to biofuels

Clearly throughout history, national governmental policies (currently motivated by the benefits discussed in the chapter’s introduction) appeared to be fundamental driving forces triggering the biofuel sector. Changes in laws and regulations have had large impacts on the sector. From this perspective, Brazil’s experience illustrates best, that it is possible to successfully mandate large-scale shifts to biofuel use through policy intervention. However, biofuel policy frameworks are complex and can conflict indeed with existing laws and regulation (e.g., the European fuel quality standard). The lesson which can be drawn from the case-study is that the political commitment should be translated into effective biofuel-promoting policies that are (1) clear and consistent over a longer period of time, (2) non-bureaucratic, transparent, compatible, and without the possibility to misinterpret them, and (3) specific for the national situation to optimally exploit available resources. These points all applied in the Brazilian context. Consequently, this lesson confirms the theoretical prerequisites for successful transition management of an approach-committed, active government carefully directing and orchestrating over the long-term, and should be surrounded by a broad sense of urgency (table 5).

However, the crux is that these national biofuel-promoting policies (if available) vary strongly across (European) countries and US states. Combined with the fact that the main biofuel demand and the largest supply potential do not geographically coincide (and thus inherently evoke cross-border matters), this results in major obstacles for international agreed regulations, cooperation, trade, etc. Thus, although in theory the three principle characteristics pointed out above about biofuel-promoting policies are valid for the individual country, they may seriously barricade a global biofuel economy if national policies diverge largely. This ‘lesson from lesson’ introduces a subsequent vital aspect from which lessons can be learned, i.e., international collaboration.

#### International collaboration

The critical issues section in the case-study (section 7.4.3) elaborates on the crucial importance of trade/tax schemes, biofuel quality standards, sustainability criteria, a certification framework, among several others, to facilitate a successful biofuel transition process worldwide. Common factors involved in all critical issues discussed are international collaboration, agreement, and alignment on policy- and industry-level. Evidently, the main lesson is that a far-reaching international approach is indispensable with respect to the set up of a global biofuel economy. Clearly, addressing the cross-



border critical issues as discussed in the case-study deserves then high priority and central attention in this international context. Succeeding this challenge will improve among many others, the investment climate for biofuels by all stakeholders, e.g., industry compliance to develop further advanced technologies (e.g., FFVs, second-generation biofuels), consumers' willingness to adopt these technologies, and governments granting financial incentives with less hesitation. Ultimately, a comprehensive international approach alleviates the presence of earlier discussed obstacles of structural nature like the chicken-and-egg dilemma and the prisoners' dilemma.

Referring back to the transition management system's principles as portrayed in table 5, no explicit indication of this lesson is found. Consequently, a shortcoming is identified (or at least a noteworthy underestimation) with respect to this message. Explanations for this apparently omission are perhaps (1) the fact that the transition management system is developed as policy tool mainly for uses within the national Dutch boundaries, and (2) the fact that the system is still in its infancy, not yet brought to perfection. Obviously, tweaking the current transition management system towards an international level is possible without thwarting its underlying principles. This deserves however further systematic scientific investigation. After the technology- and political-oriented lessons, the final sub-section illustrates lessons around biofuels' economics.

#### Consistent economic support mechanism

Biofuels are not yet cost competitive with petroleum fuels without subsidies or tax incentives, except in situations where petroleum fuel prices are exceptionally high, and biofuel production/distribution costs are relatively low. Consequently, economics is a great barrier to widespread development of the global biofuels industry, and closely linked to the availability and world price of oil. Hence, compensation to bridge the financial gap with petroleum fuels is indispensable, and has proven to be a very effective means for creating favorable market conditions for biofuels (e.g., in Brazil). However, the historical and regional inspection reveals too that fiscal support mechanisms (1) often do not reckon with all beneficial biofuels' externalities, (2) differ significantly per country/state in implementation and execution, and (3) in combination with relevant policies are unable to guarantee at forehand that targets for biofuels' market penetration will be met. In many European countries and US states this results in constant adjustments and revisions of tax exemption levels, subsidies, etc. The uncertainty around fiscal support mechanisms clearly affects the biofuels' supply and demand, investment climate, societal expectations, among many other aspects. Obviously, a longer-term, robust, and transparent financial support mechanism is necessary, ideally again on a cross-border level. Fortunately, this is recognized and currently subject of discussion at the European layer, and provisionally captured in fuel taxation directives. The considerations above are in harmony with the transition management principles of the willingness to invest in energy transitions, the necessity of trust relationships between the participating actors (in this case the involved countries/states), and the use of long-term considerations as framework for short-term actions (table 5).

From a historical point of view, economics have ever been a vital decisive factor for the application of biofuels. Several methods are proposed and employed to finance the afore-mentioned gap. For instance, governmental bodies may raise petroleum fuel taxes, or financially penalize the use

of more polluting vehicles.<sup>44</sup> The added income could then be used to fund the promotion of biofuels' supply and demand at the industry and consumer level. Economies of scale may also be reached when biofuels (and its co-products) are linked with a broader biomass and bioenergy system (e.g., electricity and heat production). Additionally, under the Kyoto-protocol, trade in carbon credits is frequently applied between developed and developing regions. In sum, the economic outlook of biofuels worldwide can effectively be improved without heavy losses.

### **5.2.3 Concluding words**

Biofuels are not new. Its long history reveals interesting insights about the prerequisites for successful future global-scale deployment. However, experiences are mostly context and country specific which makes it difficult to provide valid and general-applicable advice, i.e., for a worldwide biofuel-economy. The most important lesson is the need for long-term, stable international commitment and cooperation in the field of policies, R&D, (financial) support mechanisms, and knowledge valorization. Established industries (e.g., oil suppliers and car manufacturers) as well as small innovative firms, and societal groups have to be involved in this international arena. Under all circumstances, governmental bodies should improve market conditions and the investment climate wherever possible. Capacity is then strengthened which shapes the required momentum to deal with for instance the obstacles of structural nature like the chicken-and-egg dilemma and prisoners' dilemma. Compared to conventional petroleum-based fuels, biofuels' economic outlook can be improved through for instance novel (financial) support mechanisms. On the other hand, the growing world price of oil assists in this challenge too. To a large extent, the transition management principles, rules of thumb, and preconditions as presented in table 5, correspond closely with (past) biofuels' experiences, and the lessons learned presented throughout the section. Consequently, this approach may be suited to 'fuel' the transition towards a substantial, global biofuel-breakthrough. Though, the preliminary challenge is then to tweak and employ the transition management train of thoughts into a full international context. Subsequently, critical issues must be addressed, which is an additional cross-border challenge if biofuels are to become a truly international commodity.

## **5.3 Discussion of research question 5**

### **5.3.1 Introduction**

The previous section provided basic knowledge and insights about biofuels, based on a historical and past experience perspective. To complete the picture, an analysis of the market position and its expected future potential on a short- and longer-term is necessary. As a result, more deliberate advice can be given with respect to the biofuel value-chain and its longer-term development strategy. The final research question addresses this need and reads: "what is biofuels' global market position, and what regional market conditions are in place around Rotterdam that could stimulate the set up of the biofuel value-chain?"

---

<sup>44</sup> Fuel taxation is seen today as the best available fiscal tool to control the amount of petroleum fuels used, and hence energy consumption and emissions from the transportation sector since it is the only pricing instrument that is directly related to vehicle usage (Steenberghen & López 2007).

The market analyses in the subsequent sub-sections are divided into 3 levels, i.e., the global, national, and regional level.

### 5.3.2 Elaboration Q5: Biofuels' market prospective

#### Global-scale analysis

Up to now, bioenergy and biofuels are primarily produced from 'traditional' feedstock materials (i.e., energy crops and agricultural residues). For the time being, and probably for coming decades, this method represents, at least economically-wise, the most viable. As discussed before, (intercontinental) trade in biomass and biofuels already takes place on bilateral agreements. Figure 12 shows some significant existing trade-routes for ethanol, pellets, and agricultural residues as described in IEA/T40 (2006), and confirms the supply-demand direction towards developed regions.<sup>45</sup> Noticeably, especially Europe receives a variety of biomass feedstocks from over the world.

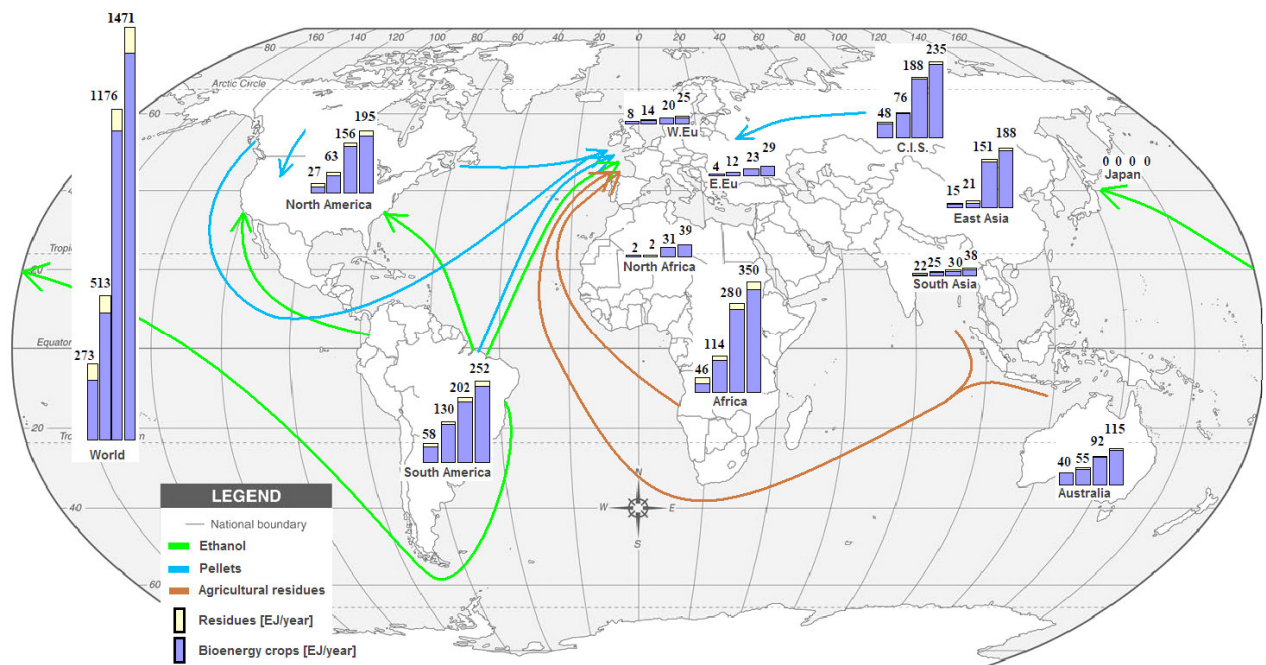


Figure 12: Existing trade routes according to IEA/T40 (2006) and the theoretical bioenergy potential in 2050 per region and for the world according to four scenarios in Smeets, Faaij & Lewandowski (2004) (Source of world map: <http://chuma.cas.usf.edu/~juster/volc1/world%20map.gif>)

Moreover, figure 12 provides as well an estimation of the total theoretical potential for bioenergy production (from crops and agricultural residues) in 2050 per region, and according to four scenarios analyzed by Smeets, Faaij & Lewandowski (2004). Future estimations about bioenergy abound in literature. Though, specifically this scenario analysis is selected since it is carried by taking into account previous findings and available knowledge on different factors that determine the potential of bioenergy production. As a result, one might conclude that this 'meta-scenario analysis model' with bottom-up approach, may produce a more reliable outcome. The key elements used throughout the analysis are population growth, capita food consumption and composition, land use patterns, crop

<sup>45</sup> Although present, inter-European trade is not displayed for clearness.

yields (food crops and bioenergy crops), efficiency of the animal production system, feed inputs in the animal production system, wood consumption and production, and natural forest growth. The scenarios focus in particular on the impact on land use of the level of technology used in the agricultural production system. A large number of variables are included in the study. The factors with the highest impact on the dependent variable are discussed for each scenario in table 8.

**Table 8: Overview of the scenarios and factors (Smeets, Faaij & Lewandowski 2004: p.41)**

Factor	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Feed conversion efficiency	High	High	High	High
Animal production system used (pastoral, mixed, landless)	Mixed	Mixed	Landless	Landless
Level of technology for crop production	Very high	Very high	Very high	Super high
Water supply for agriculture (rain-fed = r.f., irrigated = irri)	r.f.	r.f./irri	r.f./irri	r.f./irri

Furthermore, scenarios 1 to 3 have in common that they are based on (1) a medium population growth, (2) medium increase in per capita food consumption, (3) a high plantation establishment scenario, and (4) high level of technology for the production of bioenergy crops. Scenario 4 is based on the assumption that R&D efforts may increase yields above the existing level of technology used in the other scenarios (Smeets, Faaij & Lewandowski 2004). Any further elaboration on the study falls beyond the report's scope. Nonetheless and despite many uncertainties related to the data and scenarios, from the inspection several important contextual conclusions can be drawn with respect to the biofuel value-chain in Rotterdam region. First, overseas trade routes towards Western Europe already exist for a variety of biomass feedstocks and bioenergy types, and are likely to be intensified in the future. Obviously, the Port of Rotterdam may become a significant player in adding value to all types of biomass and bioenergy being traded overseas towards Europe. Furthermore, by considering the world energy demand (currently about 430 EJ/year<sup>46</sup>), even the most pessimistic scenario (i.e., scenario 1) shows that a substantial amount (273 EJ/year) of that demand can be captured by bioenergy in 2050.<sup>47</sup> Evidently, such amount represents no niche applications but true worldwide commodities, also for road transportation biofuels. Finally, the analysis covers a longer period of time (over forty years). At least until then, the prospects related to bioenergy are rather positive, which reduces the financial risks of long-term investments in large-scale bioenergy systems at strategic sites (e.g., the Port of Rotterdam).

#### National analysis

Until 2000, the Netherlands barely imported biomass for energy production. Though, over the last few years, both the import and export of biomass for energy purposes have been strongly increased, and up to a factor of seven in terms of electricity produced between 2003 and 2005 (Junginger, de Wit, Faaij 2006). This increase is mainly attributable to the set up of the GAVE program in the late 1990s by the Dutch government,<sup>48</sup> as a response to the Kyoto Protocol. Briefly, the two-phase program aims an accelerated introduction of renewable energy sources in the Netherlands. The first phase (1998-

<sup>46</sup> According to Faaij & Domac (2006).

<sup>47</sup> Although world energy demand in 2050 is expected to be much more than to date (fig 6), the amount of 273 EJ/year from bioenergy remains a substantial part of the future energy needs.

<sup>48</sup> On behalf of the ministries of Spatial Planning, Housing and the Environment; Economic Affairs; and Transport, Public Works, and Water Management.

2000) aimed at exploring the perspectives for introducing new, clean, gaseous and liquid energy carriers on the Dutch market by means of demonstration projects. The second phase (2001-2010) focuses on demonstrating production chains for the most promising options following the steps of (1) establishing alliances between stakeholders, (2) developing blue prints for the demonstration phase, (3) realizing demonstration projects, and (4) introducing production and use on the market (SenterNovem 2007). The activities for both, the development and the demonstration projects receive (partial) financial support.

As far as biofuels concern, the GAVE program focuses at supporting the government and relevant market parties in their efforts within the framework of the EU Biofuel Directive. The Dutch government initially not intended to promote first-generation biofuels. After issuing several studies (e.g., Gave 2003), it was namely concluded that these biofuels were not cost-effective in reducing GHGs. Consequently, fiscal support was only granted for second-generation biofuel development projects. However, under pressure of rapeseed oil producers, local governmental bodies, and the EU Biofuel Directive, the Dutch government decided to make a start with a market for biofuels (Thuijl & Deurwaarder 2006). In March 2006, a general fiscal support for biofuel blends became effective. A tax exemption was granted for a maximum biofuels volume incorporated in a blend of 2%. Both, biodiesel and ethanol were eligible for the tax exemption, ensuring that the developments initiated in both markets. As a result, several companies started blending biofuels (e.g., Shell (gasoline with ETBE), Argos Oil (E5 and E85)). However, market parties and financiers remained hesitant to invest in new biofuel production installations due to the unfamiliarity with biofuels and their uncertain policies.<sup>49</sup> In 2007 already, the tax exemption was cancelled. Instead of fiscal support, fuel suppliers are now obliged to sell at least 2% (on an energy basis) of biofuels of their annual fuel sales.<sup>50</sup> Those not complying get a financial penalty. In the coming years, the obligatory target will be increased gradually towards a minimum of 5.75% in 2010, which then corresponds with the targets set by the EU Biofuels Directive. The most recent figures by the CBS show indeed a considerable increase of biofuel sales in the Netherlands. Biofuels' share in the 2005 road transportation fuel market was merely 0.02%. Due to the tax exemption in 2006, its market share increased to 0.4% (i.e., 67 million liters), and is currently on course reaching the 2% market share (i.e., 335 million liters) in 2007 by means of the afore-mentioned policy measure.<sup>51</sup> In sum, the biofuel legislation now employed in the Netherlands provides a more transparent and clear structure, evidently, reducing the perceived risk in terms of future investments in large-scale bioenergy systems in the Netherlands.

Since the Dutch government to date (finally) acknowledges the need for first-generation biofuels to meet the short-term biofuels targets, also domestic production of this type receives attention. A fact finding study by the Gave program concluded that the Dutch potential biomass availability is about 80% higher than the 2% target of the EU Biofuels Directive (Gave 2003). Currently, the province of North-Brabant is seriously exploring the possibilities to produce energy crops for this purpose. However, the study concluded too that, anticipating on the amount of biofuels necessary for reaching the 5.75% target, the Dutch demand in 2010 is 70% higher than the potential

---

<sup>49</sup> As explained by HE Blends BV (producer of E10-E26 hydrous ethanol) during a meeting at TNO M&L, Mai 11<sup>th</sup>, 2007.

<sup>50</sup> Via: <http://www.cbs.nl/nl-NL/menu/themas/industrie-energie/publicaties/artikelen/archief/2007/2007-90052-wk.htm>.

<sup>51</sup> Source: see footnote 50.

domestic biofuel production.<sup>52</sup> Consequently, one might conclude that a substantial import of biofuels is inevitably already on the short-term, in order to meet the EU targets.

According to SenterNovem (2007), the Dutch central government has allocated a budget of 60 million Euro for the period 2006-2010. This financial support aims mainly on the development of advanced biofuel production technologies. Projects applying for a subsidy should meet the following criteria: (1) achieve an improved GHG balance and lower land-use, (2) market potential and chance of success, (3) taking into account cost reductions as a result of technological learning (i.e., learning curve effect), (4) subsidy-effectiveness, and (5) other environmental benefits (Thuijl & Deurwaarder 2006). As a result, various initiatives have started and are under development to produce or import biofuels, such as ethanol, biodiesel and pure plant oil (PPO). Additionally, a few initiatives in different parts of the Netherlands for busses, trucks, agricultural vehicles and boats (partially) fuelled with biodiesel or PPO have been realized (Junginger, de Wit & Faaij 2006). However, compared to for instance Germany, the Netherlands lack behind significantly in terms of biofuel use, R&D budgets, etc. (measured per capita). Table 9 provides an overview of all stakeholders involved with the production, import & distribution, and use of biofuels in the Netherlands according to SenterNovem (2007). Additionally, figure 13 provides a geographic overview of these projects and initiatives.

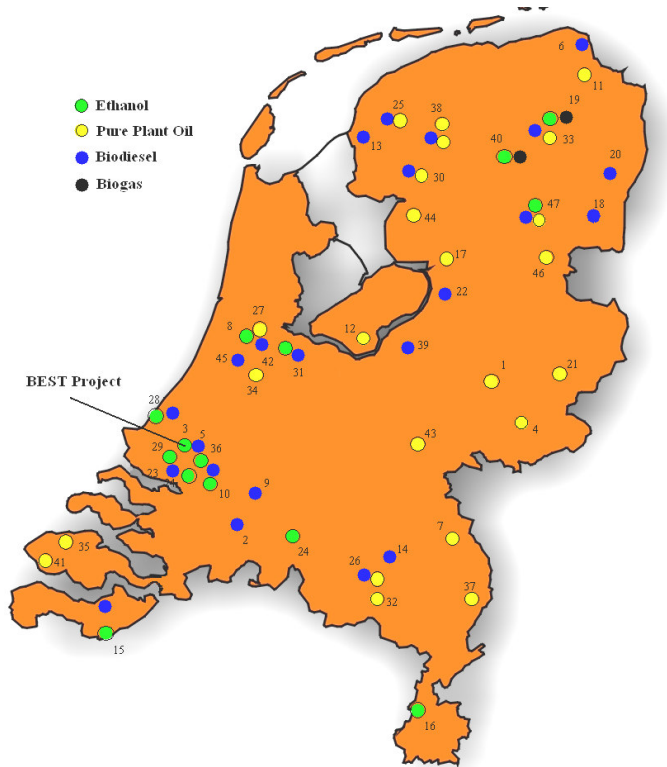
**Table 9: Stakeholders involved in biofuel projects and initiatives in 2006 (source of data: <http://gave.novem.nl/gave>)**

Biofuel production	Biofuel import & distribution	Biofuel use
1 Achterhoekse Oliemolen: ppo	23 Archer Daniels Midland: biodiesel	32 BBA: ppo
2 BeWagroep: biodiesel	24 Argos Oil: ethanol	33 Bioliquid: ppo & biodiesel
3 BEST Rotterdam: ethanol & biodiesel	25 Delta Oil: biodiesel & ppo	34 Bloemenveiling Aalsmeer: ppo
4 Biofuels: ppo	26 Diligent Energy Systems: biodiesel & ppo	35 Gemeente Noord-Beveland: ppo
5 Biopetrol Rotterdam: biodiesel	27 Green Planet: biodiesel, ethanol & PPO	36 Gemeente Rotterdam: ethanol & biodiesel
6 Biovalue: biodiesel	28 NEWNRG: ppo	37 Gemeente Venlo: ppo
7 Coöperatie Carnola: ppo	29 Shell Nederland: ethanol & biodiesel	38 Omrin: ppo
8 Futura Petroleum Ltd. - Harvest Biofuels: ethanol	30 VOPAK: ethanol	39 Polskamp Meat Industries Vleesverwerkende Industrie: oil fats
9 Golden Hope: biodiesel	31 Wiersma & Zn. Oliehandel: biodiesel	40 Provincie Fryslân: biodiesel & ppo
10 Lyondell Chemie Nederland: ethanol	32 Zero-e: ethanol & biodiesel	41 Provincie Zeeland: ppo
11 Noord Nederlandse Oliemolen: ppo		42 Rederij P. Kooij: biodiesel
12 OPEK Nederland: ppo		43 SITA - McDonalds: ppo
13 PPO Groeneveld: ppo		44 Solaroilsystems: ppo
14 Rendac, a Sobel company: biodiesel		45 TPG Post Pakketservice/TNT: biodiesel
15 Royal Nedalco, Sas van Gent: ethanol		46 Verkeersschool Nijland: ppo
16 Sabc: ethanol		
17 Stimuland Overijssel: ppo		
18 Sunoil Biodiesel: biodiesel		
19 Technologie Centrum Noord-Nl: ethanol & biogas		
20 Ten Kate: biodiesel		
21 Twentsche Oliemolen: ppo		
22 Vierhouten Vet & Biodiesel Kampen: biodiesel		

The policy support, with an emphasis on R&D efforts directed towards advanced second-generation biofuel production, is in line with the rather high innovation-driven mentality of Dutch entrepreneurs, universities, and research organizations. The Netherlands hold a broad base of knowledge in the field of (bio-)chemical energy, energy-conversion, process-technologies, and the application of these in

<sup>52</sup> In general, the Dutch biomass potential for ethanol is higher than for biodiesel, due to the availability of suitable residues for ethanol production (Gave 2003).

novel settings. Additionally, the rather advanced Dutch agro-food- and petrochemical-industry may make a valuable contribution too, in favor of the biofuel value-chain in terms of production and research efforts. On the other hand, specific co-products from the value-chain may serve as (raw) input material for the afore-mentioned industry sectors. Furthermore, from a strategic-national point of view, investing in a large-scale biofuel sector makes sense, in that it may compensate the expected reduced revenues and domestic energy availability from the national natural gas fields, in the long-term.



**Figure 13: Geographic overview of all projects involved with the production, import & distribution, and use of biofuels (ethanol, biodiesel, ppo, biogas) active in 2006 (the inventory is based on data from table 9 and linked with the location of each project/initiative in the Netherlands)**

Figure 13 clearly shows that several ethanol- and biodiesel-related explorative initiatives have started around the Port of Rotterdam, indicating a rather positive regional outlook. The next sub-section analyzes more in-depth the regional strengths.

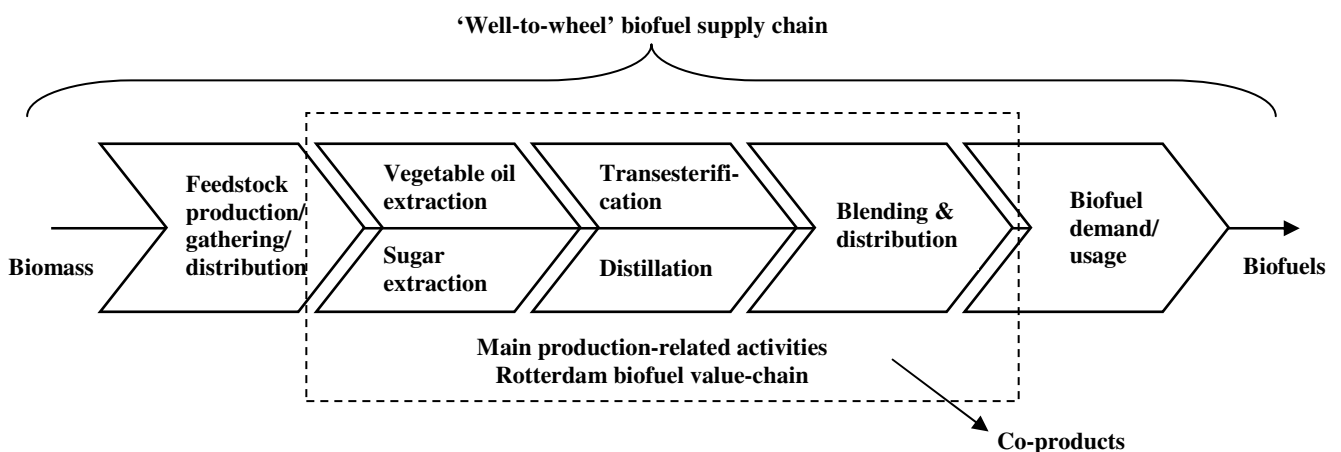
Regional analysis

The Port of Rotterdam is currently Europe’s largest port in terms of throughput volume, and acts as Europe’s largest logistical and industrial key transfer point.<sup>53</sup> Besides size, its history and strategic location are important factors that attract industry and services for more than a century. As far as energy, oil, and chemicals concerns, the port now hosts six oil refineries, over forty (multinational) chemical manufacturers with large-scale facilities, numerous tank storage terminals, and distribution companies. In fact, the (petro-)chemical cluster accounts for more than 50% of the revenue of the Port of Rotterdam, and for 60% of land use (F&F/PoR 2007). By means of well-developed (inter)national connections via road, railway, inland- and coastal-navigation, and pipeline systems, the port serves as

<sup>53</sup> Via: [http://www.portofrotterdam.com/nl/feiten\\_cijfers/beschrijving\\_haven/index.jsp](http://www.portofrotterdam.com/nl/feiten_cijfers/beschrijving_haven/index.jsp).

the main port of Northwest Europe. According to PoR/YCPC (2006), one of the key features in the Port of Rotterdam is the realization of economies-of-scale through strong cooperation between oil- and chemical-concerns. One company's end- or co-product is frequently another's raw material. This cooperation has a significant impact on both investment and operating costs for companies at the port. Furthermore, the port is the European axis for agricultural products and, as far as vegetable fats and oils concerns, even market leader in Europe.<sup>54</sup> Also recycling companies abound in the area, serving the variety of industries with waste management services. Obviously, due to the presence of various related markets and distribution channels, a significant strategic potential in the broadest sense arises for the large-scale biomass-to-biofuel processing value-chain at the Port of Rotterdam. This applies for the core-products like biomass and biofuels, but also for the co-products released.

Appendix D illustrates the (cross-border) supply side for the value-chain. In general, no distinction is made between biodiesel, ethanol, first-, and second-generation biofuels since these all may follow the indicated transportation flows and modalities. By considering the complete supply chain, from biomass feedstock production (well) to biofuels' application in the road mobility system (wheel), the Rotterdam biofuel value-chain is positioned in the middle. Figure 14 roughly sketches this position and the production-related activities (for biodiesel and ethanol) of the value-chain.



**Figure 14: Supply chain and projected main production-related activities in the Rotterdam biofuel value-chain (activities for biodiesel and ethanol production, based on the case-study)**

In order to give an idea about the diversity of markets at the Port of Rotterdam, table 10 identifies and distinguishes five industry types that may benefit directly from the presence of a large-scale biofuel value-chain. On the other hand, the chain takes too advantage from the established industries and infrastructures. For instance, the biofuel value-chain may supply the required biofuels to the oil refineries. Additionally, the chemical industry may adopt the chain's co-products like glycerin and bioplastics. Remainders from the food industry may serve as biomass feedstock, whereas the chain's protein-rich remainders can be sold as animal feed. The agro-food industry at the port includes large grain- and starch-processing facilities for which the biofuel value-chain may act as additional distribution channel. A coalition with recycling industries may direct R&D efforts towards waste-to-

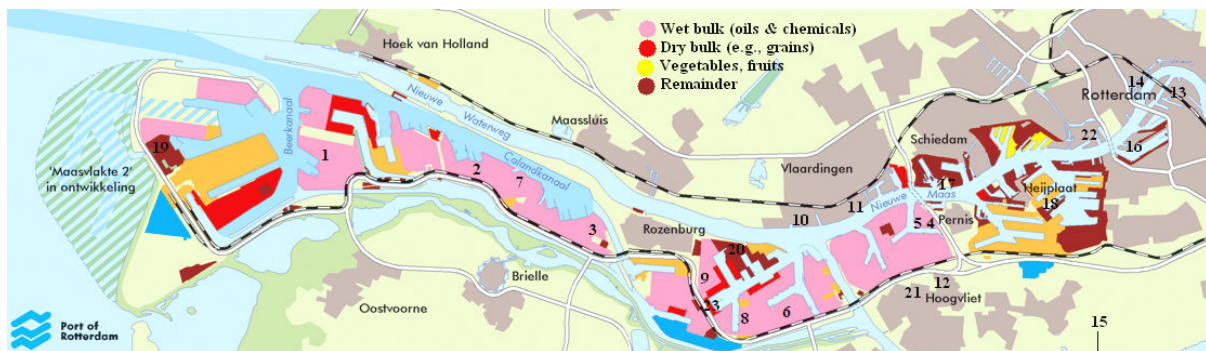
<sup>54</sup> To date, around 10 million tons of dry agro-bulk and 5 million tons of vegetable fats and oils are transferred per year via the port (via: [http://www.portofrotterdam.com/nl/business\\_informatie/industrie/agri\\_business/index.jsp](http://www.portofrotterdam.com/nl/business_informatie/industrie/agri_business/index.jsp)).



bioenergy processes. Obviously, the present tank terminals can be used for temporary biomass and biofuel storage. In sum, integration of the biofuel value-chain in a variety of markets at the Port of Rotterdam seems possible, which then creates a strong strategic potential. Finally, figure 15 provides a geographic overview of the companies presented in table 10.

**Table 10: Biofuel value-chain's related markets at the Port of Rotterdam, and some examples of companies**

Oil refineries (6)	Chemical manufacturers (40+)	Agro-food (10+)	Recycling (20+)	Tank storage terminals (dry bulk & liquids) (20+)
1 Nerafco (BP, Texaco) 2 Kuwait Petroleum 3 Koch HC Partnership 4 ExxonMobil 5 Shell Nederland 6 Esso Nederland	7 Caldic Chemical 8 Akzo Nobel 9 DSM spec. prod. 10 Hydro Agri 11 Lever Fabergé ...	12 Kog Edible Oils 13 Unilever 14 AC Troepfer Int. 15 Unimills 16 Provimi ...	17 SITA 18 AVR-van Ganswinkel 19 Biomass Nl. 20 Groen Recycling ...	21 Argos 22 Vopak 23 Maas Silo ...



**Figure 15: Geographic overview of the companies presented in table 10 at the Port of Rotterdam (Port map edited from: [http://www.portofrotterdam.com/nl/feiten\\_cijfers/havenkaarten/branches/index.jsp](http://www.portofrotterdam.com/nl/feiten_cijfers/havenkaarten/branches/index.jsp))**

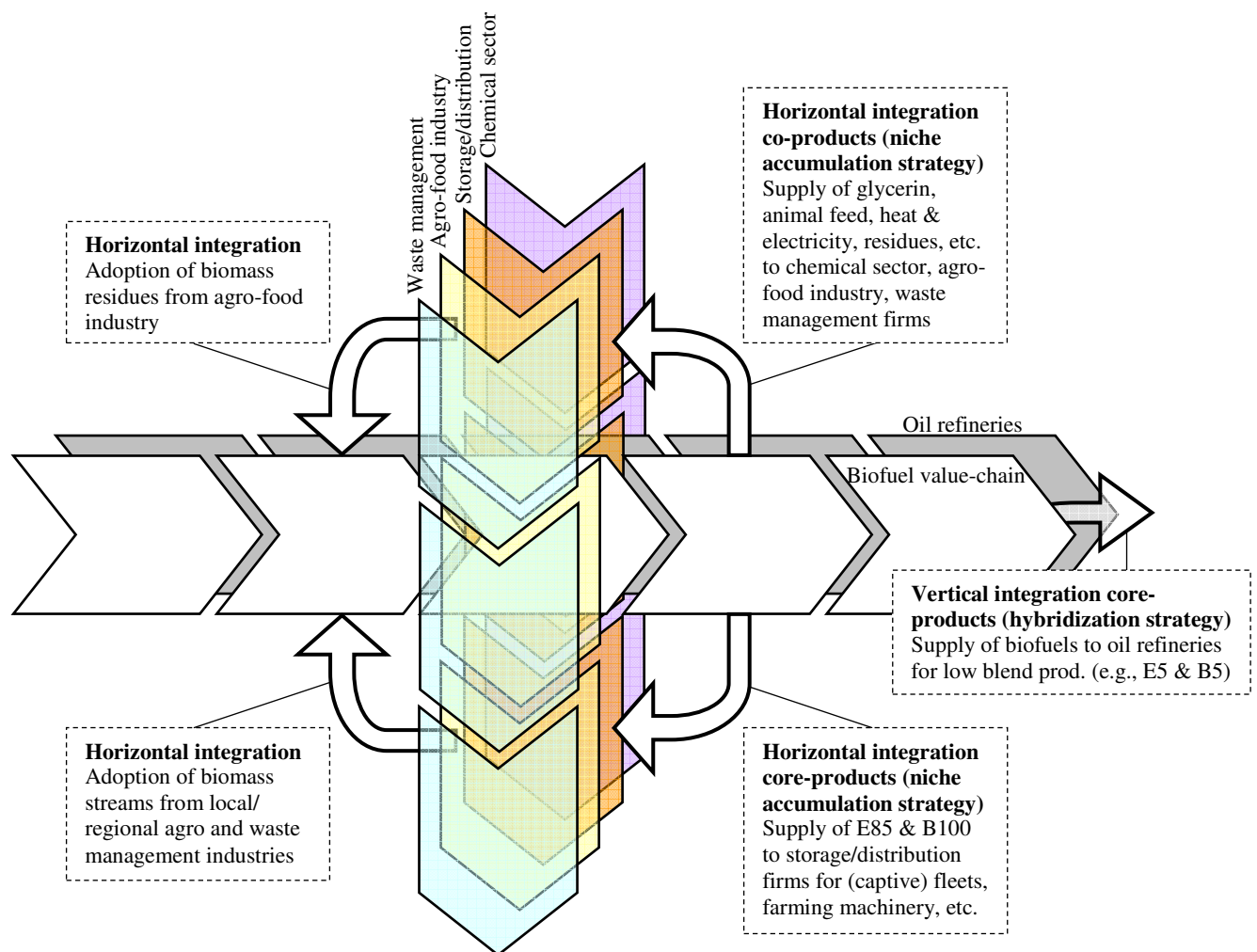
### 5.3.3 Concluding words

From a global perspective, the potential availability of biomass-for-energy purposes by 2050 equals at least to 75% of the current total energy demand. More optimistic scenarios even estimate a bioenergy potential of up to 3-4 times the current world energy demand. Despite the uncertainties around longer-term bioenergy scenario analyses, the rather considerable theoretical potential verifies bioenergy's relevance and global market position as commodity, also in the form of liquid road transportation fuels. Combined with the expected global increase in bioenergy demand, investments in large-scale bioenergy-related production facilities are substantiated when these are located at strategically attractive sites (e.g., the Port of Rotterdam).

Both, biomass-for-energy and biofuels are currently increasingly traded overseas by bilateral agreements, and towards a variety of European destinations. In this context, the Port of Rotterdam acts already as key transfer point for Europe. However, since typically and merely transfer activities are carried out instead of value added activities, the economic potential concerning bioenergy is, by no means, abundantly exploited at the port. One of the causes may be that the Netherlands has not a tradition in producing or using large amounts of bioenergy. Moreover, the market conditions and investment climate have been very uncertain recent years, due to frequent changing economic incentives and policy measures. Nonetheless, the current 2007 legislative framework (obliging an

increasing percentage of biofuels share in petroleum-derived road transportation fuels over the next three years) follows the EU Biofuels Directive's targets, which provides a relative clear and stable outlook as far as liquid biofuels concern. As a result, short-term biofuel demand can be estimated fairly precise, for the Netherlands, but also for Europe. The Dutch longer-term policy strategy for bioenergy (i.e., second-generation biofuels) fits well with the national entrepreneurial tradition and innovative strengths. The present advanced industry sectors (e.g., (petro-)chemical, agro-food industry) and research organizations may make a valuable contribution to the commercial development of future second-generation biofuels.

The Port of Rotterdam possesses a unique set of characteristics from which the large-scale biofuel value-chain can benefit. Among many others, the chain can (1) use the port's established infrastructures and logistical services, (2) supply its biofuels to neighboring multinational oil refineries (with distribution channels to Western Europe), (3) adopt biomass residues from the local agro-food industry, and (4) supply its co-products to other markets and value-chains at the port. Obviously, a substantial strategic and economic potential for a large-scale biofuel value-chain is present at the Port of Rotterdam. Figure 16 schematically clarifies some important operations-related vertical and horizontal chain integration possibilities, and is further discussed in the following chapter.



**Figure 16: Operations-related integration opportunities (horizontal and vertical) of Rotterdam biofuel value-chain for core- and co-products, according to the hybridization and niche accumulation market introduction strategies**



## **6 Discussion and conclusions**

### **6.1 The framework with recommendations**

#### **6.1.1 Introduction**

The central report's research objective is to provide advice for increasing biofuel-related economic activities in Rotterdam region, by presenting a framework with preliminary recommendations for the creation and development of a large-scale biofuel value-chain in that region. This section elaborates on that framework by collecting, structuring, and summarizing the critical ingredients presented throughout the previous chapters.

The framework consists of two parts. The contextual recommendations represent those elements that cannot, or hardly, be influenced by the biofuel value-chain. However, these elements are essential prerequisites for the (future) viability of the complete chain. The principles from transition (management) theories run through the elaboration of this part. The second part consists of value-chain specific recommendations and is largely based on part B (i.e., chapter 5) of the report. An overview of the framework is given in sub-section 6.1.4. For both parts, the key critical factors, their main rationales, and examples of implementation are given.

#### **6.1.2 Contextual recommendations**

##### International collaboration

By considering the longer-term aspirations of for instance the EU Biofuels Directive, an international collaborative approach around biomass and biofuels is indispensable, and represents the first key critical factor. In order to strengthen capacity, 'noses have to point in the same direction'. This can be realized by building an international network (or platform) between all relevant stakeholders, also from dominant, not directly related, sectors like oil companies and car manufacturers. By means of a transition arena and cross-border/sector discussions (e.g., workshops), a shared understanding and long-term vision about biofuels can be shaped. This 'blueprint' (i.e., the transition agenda), set up by governmental bodies, industry partners, societal groups, among others, should form the basis for any biofuel-related project or activity (e.g., (inter)national R&D projects, development and refinement of certification system and quality standards). Consequently, obstacles of structural nature like the prisoners' dilemma and the chicken-and-egg dilemma can be overcome. Additionally, an international collaborative approach better facilitates cross-border exchange of experiences and the exploitation of learning effects around biofuels.

##### Biomass certification system

Large-scale utilization of biofuels introduces critical issues on many dimensions (e.g., food competition, biodiversity, socio-economic aspects). An elaborated and internationally supported certification system for biomass represents a means to address these critical sustainability issues. Such system can ensure global minimum socio-economic and ecological standards. However, since biomass feedstocks and the situations in which these are produced may differ significantly, the criteria used in the certification system must be able to deal with contextual characteristics. Furthermore, the monitoring system that traces the biomass along the supply chain must consist of indicators (preferably quantifiable) that can be assessed in practice in a convenient and transparent manner.

### Common biofuel quality standards

If biomass, bioenergy, and biofuels are to become truly international commodities, cross-border trade (and thus trade schemes) in these products is a fundamental element. Biofuel quality standards enable fair market dynamics (supply and demand) and ultimately competition. In addition, quality standards provide a means to gain acceptance, approval, and confidence about biofuels by the general public and industries, and to ensure compatibility with vehicle fleets and infrastructures. Finally, it is arguable that quality standards combined with a robust certification system may induce voluntary industry agreements concerning the wider application of biofuels, its related technologies, and demonstration/R&D projects. Obviously, the standardization process should be initiated by the international platform of stakeholders. In this context, governmental bodies should steer the process, whereas industry partners and other NGOs contribute content-wise to the process.

### Political commitment

By means of a broad political commitment within a country or region, the international biofuel transition agenda can be translated into national operations- and R&D-related activities. At a national-level, central governmental bodies must shape momentum, initial favorable market conditions, and an improved investment climate. Besides providing economic incentives, this can be done by employing (and continuing) legislative measures that oblige for instance a given percentage of biofuels on the national road transportation fuel market. As a result of this ‘forced’ market creation, demand can be estimated easily and public and industry awareness about biofuels increases. This should be supported by information dissemination campaigns about biofuels and its benefits (e.g., via demonstration projects, media campaigns, car labeling), which aim for acceptance and increased willingness to adopt. National governmental bodies are also committed to perform legal audits along the supply chain of the biomass-to-biofuels process, and to ensure the biofuel product is in accordance with the rules (i.e., the certification system and the biofuel quality standards). Furthermore, governmental bodies at the regional- and local-level can increase demand of niche biofuels like B100 & E85 by putting dedicated vehicle fleets into use. Clearly, the term ‘political commitment’ in this context is broad and, in all probably, not fully captured in this elaboration. Nonetheless, an idea is sketched about the importance and the diversity of political involvement.

### ***6.1.3 Rotterdam biofuel value-chain specific recommendations***

#### Chain integration

The integration opportunity of the biofuel value-chain in the present context (i.e., the Port of Rotterdam) is a key critical factor, in that it improves, and even secures, the overall long-term viability. On the operations-level (e.g., processing, production, and distribution of biofuels), the chain must integrate with existing oil refineries. In business management terms, this is often referred to as vertical integration since the core-products from the biofuel value-chain are up-streamed in another value-chain for similar products and market purposes. Accordingly, this provides a means to apply the hybridization introduction strategy for biofuels, in which it acts as ‘add-on’ element, provides the so-called ‘critical mass’, and is brought to the market via existing infrastructures and distribution channels. In contrast, horizontal integration concerns the exploitation of products in and from (un)related sectors and markets. In case of the biofuel value-chain, its co- and core-products can

follow this option. Especially the established chemical sector, storage- and distribution-facilities, the agro-food industry, and the waste management companies can adopt both, co- and core-products. Consequently, the niche accumulation strategy is then applied. For instance, the co-product glycerin, resulting from biodiesel production, can be supplied to chemical manufacturers. On the other hand, core-product E85 can be delivered to fuel distribution companies to supply the market. In the 'horizontal setting', the biofuel value-chain may also adopt co- and core-products from existing sectors (e.g., residues from the agro-food industry), to be processed into biofuels. Obvious advantages of integration are reduced transaction costs (e.g., transportation costs), the creation of local supply and demand markets, and the possibility to exploit synergy effects. The integration possibilities are visualized in figure 16.

Besides operations-related integration, R&D programs can be shared too. Supported by governmental incentives, research organizations (e.g., TNO, ECN) and universities (e.g., the Eindhoven University of Technology, Wageningen University) can co-ordinate research programs and co-develop for instance process technologies for advanced, second-generation biofuels. In such setting, the biofuel value-chain may act as test lab, also for instance for oil companies.

#### Scale effects

Parallel to integration, the biofuel value-chain must take advantages of scale effects in order to grow. Substantial production volumes call for larger equipment series, which in turn results in higher overall efficiency and reduced costs. Likewise, as size increases, learning effects can be achieved more easily. An optimal exploitation of chain integration and scale effects enables a higher degree of flexibility and scope too (i.e., possibility to process different biomass feedstocks).

Indirectly, the uniqueness in size of the projected biofuel value-chain may induce several more matters of importance. For instance, the characteristics of the chain (e.g., size, centralized production and R&D, integrated in different markets/sectors, location) may create incentives for more budgets being spent on R&D activities, marketing, etc. Ultimately, this may even attract additional (international) business-related activities, and initiate positive loops.

#### Competition

When a variety of suppliers offers a given product to a large amount of buyers, competition between the multiple manufacturers, suppliers, traders, etc. takes place in order to capture a share of the market. In general, this results in either price reduction, product quality improvement, or a combination of both. Theoretically this may be applicable for biofuels too. And indeed, for biomass feedstocks this is the case, but falls beyond the value-chain's scope. Hence, the term 'competition', in case of the Rotterdam biofuel value-chain, must be approached different. Since there is only a small amount of commercial biofuel suppliers to date in the Netherlands (oil companies import most of their biofuel needs), little competition may be expected during the start up phase. Furthermore, it is even better to combine available forces (i.e., through mergers and acquisitions of the current biofuel production facilities) around the port to create the biofuel value-chain. However, although the chain receives some protection via policy measures, on the longer-term it may face substantial competition from (1) conceptually similar (international) biomass-to-biofuels sectors, and (2) end-purposes for biomass feedstock materials (e.g., heat generation, electricity production). Consequently, the chain has to be prepared for that.

### 6.1.4 The framework

Contextual recommendations		
Key critical factor	Main rationale	Implementation examples
<b>International collaboration</b> On policy-, industry-, & societal-level	Shape a common understanding through long-term vision alignment; Realization of capacity strengthening; Tackling obstacles of structural nature like the prisoners' dilemma, chicken-and-egg, etc.; Enables learning from cross-border experiences; Enables the set up of a biomass certification system, quality standards, trade schemes, etc.	International network (or platform) building between all relevant stakeholders (organization of the transition arena, multi-actor- & multi-level-approach); Set up and coordination of the international transition agenda through joint cogitation workshops about explicit biofuel-related critical issues and transition activities (e.g., experiments, certification system, quality standards, trade schemes R&D programs)
<b>Biomass certification system</b> Supported by international bodies	Elimination of unsustainable biomass; Ensuring transparency and global minimum socio-economic and ecological standards	Set up of criteria (possibly region-specific) and practical assessable indicators, employ monitoring and evaluation systems
<b>Common biofuel quality standards</b> Supported by international bodies	Enables international trade (and competition); Acquire public/industry acceptance, approval, and confidence, and ensuring compatibility; Inducement of voluntary industry agreements	The standardization process is guided by cross-border governmental bodies, content-wise the process is led by industry partners and other NGOs (e.g., research organizations)
<b>Political commitment</b> On local-, regional-, & national-level	Shape momentum and favorable market conditions through (forced) market creation (supply & demand) and preservation; Improve investment climate (on operations- and R&D-level); Increase public and industry awareness, acceptance, and willingness to adopt	Change legislation & regulatory frameworks to provide longer-term assurance about biofuels; Provide structured economic incentives; Translate international vision into steering acts for industry and NGOs (R&D & production); Public sector involvement (captive fleets); Initiate public information dissemination campaigns about biofuels' benefits through media, demonstrations, car labeling, etc.; Perform legal audits (according to certification system, quality standards, etc.)
Rotterdam biofuel value-chain specific recommendations		
Key critical factor	Main rationale	Implementation examples
<b>Chain integration</b> Vertical & horizontal on operations- & R&D-level, for core- & co-products	Transaction cost reduction (e.g., transport); Creation of local markets (supply & demand); Exploiting synergy effects and reciprocal benefits; Spreading out of R&D expenditures; Securing long-term viability (risk reduction)	Cross-sector cooperation (horizontal integration) with established chemical-, distribution-, waste management-, and agro-food-sector (niche accumulation strategy for co- & core-products) (e.g., by means of (in)formal alliance formation); Sector cooperation (vertical integration) with established oil refineries (hybridization strategy for core-products) to produce legally obliged low blend biofuels through existing infrastructures and distribution channels; Knowledge and R&D integration with established (research) organizations, SMEs, entrepreneurs, and universities (co-ordination, co-development, co-marketing, co-sitting (chain as test lab), etc.)
<b>Scale effects</b> Economies-of-scale & economies-of-scope	Improve economic outlook (higher efficiency); Facilitate the achievement of learning effects; Sector-growth through diversification results in more feedstock flexibility, etc.; Stabilization price, market (supply & demand); Uniqueness in size attracts markets and R&D (positive loops) and triggers innovation activities; Acquire positive network externalities	
<b>Competition</b> Only on the longer-term	Cost & end-user price reduction; Quality improvement	Initiate competition between end-purposes biomass (e.g., electricity, heat, biofuels); Price/quality competition with other (international) biomass-to-biofuel facilities

## 6.2 Conclusions and directions for further research

The central aim of the research is to provide a framework with preliminary recommendations for increasing biofuel-related economic activities in Rotterdam region. Essentially, a variety of research approaches could have been used to comply with this aim. In this case, a critical review in the field of transition theory, combined with scientific insights around the topic of biofuels, formed the basis and proved to be an appropriate method to build a framework aligned with the overall research objective. Moreover, the theoretical concept of the framework may be used in other situations as well, e.g., as assessment or investment tool for determining the potential of new bioenergy markets in other regions. However, its true value and generalizability can only be tested when it is actually ‘put into practice’ and evaluated, preferably in different environments. Additionally, this offers the opportunity to increase the frameworks’ level of detail.

What else should be kept in mind? In general, the reflective approach revealed that the principles behind the current Dutch transition management system, as policy tool to induce sustainability transitions, are largely in accordance with the course of business engaged in past, successful biofuel transition processes. In this reflection, the Brazilian experience turned out to be a suitable point of departure, and served as reference case. Hence, the transition management policy tool, pressurized by market pull and policy push forces (e.g., the European Biofuels Directive), is useful to drive biofuels’ societal role forward, at least within the national boundaries. Nonetheless, a significant inadequacy in transition management literature is identified too, in a sense that no explicit indication is found that emphasizes the necessity for international collaboration; evidently a crucial prerequisite in the context of the transition towards a global biofuel economy including cross-border trade schemes, quality standards, certification system, among others. Obviously, this comment evokes directions for further research.

Furthermore, the conclusion can be drawn that the Netherlands is in the favorable position to contribute significantly in the challenge of turning biofuels into a global-scoped commodity. Therefore, the Port of Rotterdam, initially surrounded by a variety of incentives, must act as leading (European) frontrunner in terms of biofuel production and research activities by exploiting untapped potentials. The points of attention and practical organization of this errand is offered throughout this report, and comprised in the framework. Horizontal and vertical chain integration with other sectors, economies-of-scale and -scope, and competition are identified as key critical factors in realizing a sustainable biofuel business at the Port of Rotterdam. Obviously, a structured open dialogue with and between potential partners, NGOs, and policy makers about the chain’s set up is a rational next step in the process. An important role for governmental bodies in the Netherlands is to increase the urgency of change and willingness to adopt biofuels by the market.

More specifically, the Netherlands, with its innovative tradition and entrepreneurial strengths, should direct a substantial portion of their R&D efforts towards inducing the transition from first- to second-generation biofuels. These advanced fuels ‘solve’ per definition most of the critical issues elaborated in this report, and extend the viability of biofuels in the longer run. However, since these fuels are not



yet commercially viable, favorable policy measures and economic incentives are indispensable to stimulate this transition process. When biomass-for-energy is embedded in society by means of stable regimes, questions will rise about the most effective purpose of biomass, i.e., for electricity, heat, biofuels, or any other. Obviously, the considerations and trade-offs to be made depend on multi-complex factors, and form an interesting 'further research' area. A sustainable energy option and business should always be the development perspective in this context.

In the end however, biofuels are no 'holy-grail solution' in road mobility and will be combined with other promising building blocks including more efficient motor vehicles, attractive mass-public transportation means, alternative fuel and propulsion concepts, among many others. Together these will help the world achieve a more diversified and sustainable transportation system in the decades ahead. In the end, the transition will shape both the nature of the fuel and vehicle industry, a process which remains highly speculative for now, but may be reviewed by transition scholars beyond mid-century.

## References

- Aggarwal P., Cha T., Wilemon D. (1998) "Barriers to the adoption of really-new products and the role of surrogate buyers", *Journal of Consumer Marketing*; vol. 15; no. 4; pp. 358-371
- Åkerman J., Höjer M. (2006) "How much transport can the climate stand? – Sweden on a sustainable path in 2050", *Energy Policy*; vol. 34; pp.1944-1957
- AGU (2003) "Human Impacts on Climate", AGU, via: [http://www.agu.org/sci\\_soc/policy/positions/climate\\_change.shtml](http://www.agu.org/sci_soc/policy/positions/climate_change.shtml)
- Amigun B., Sigamoney R., Blottnitz H. (2006) "Commercialisation of biofuel industry in Africa: A review", article in press, *Renewable and Sustainable Energy Reviews*; pp. 1-22
- ANFAVEA (2005) *Ethanol Vehicular Application Technology*, Associação Nacional dos Fabricantes de Veículos Automotores (Brazilian Automotive Industry Association, presentation at CEPAL/CENBIO/USP Seminar, São Paulo
- Atlantic (2001) "Innovation Strategies for Intelligent Transportation Systems for a Sustainable Mobility", *Institute for Technology Assessment and Systems Analysis*, Paper presented at the 8<sup>th</sup> World Congress on Intelligent Transport Systems, 30 September - 4 October 2001, Sydney
- Associated Press (2005) "World's automakers embracing hybrid vehicles: Firms trying to give customers more options to combat high gasoline prices", *Associated Press*, via: <http://www.msnbc.msn.com/id/9338664>
- Berkhout F., Smith A., Stirling A. (2003) "Socio-technological regimes and transition contexts", *SPRU Electronic Working Papers*; vol. 106, Sussex
- Brombacher A.C., de Graef M.R. (2001) "Betrouwbaarheid van Technische Systemen, Anticipereren op Trends", article for Stichting Toekomstbeeld der Techniek, Den Haag, pp. 392-417
- Brombacher A.C., Sander P.C., Sonnemans P.J.M., Rouvroye J.L. (2004) "Managing Product Reliability in Business Processes 'under pressure'", *Reliability Engineering and System Safety*; vol. 88; pp. 137-146
- Brundtland G.H. (1987) *Our Common Future*, World Commission on Environment and Development, English edition
- Butler A. (2007) "A History of Biodiesel", *Associated Content*, via: <http://www.associatedcontent.com>
- CARB (2007) "ZEV TECHNOLOGY REVIEW: Status Report on the California Air Resources Board's Zero Emission Vehicle Program", California Environmental Protection Agency Air Resources Board, via: [http://arb.ca.gov/msprog/zevprog/zevreview/zev\\_review\\_staffreport.pdf](http://arb.ca.gov/msprog/zevprog/zevreview/zev_review_staffreport.pdf)
- Cardona C.A., Sánchez Ó.J. (2007) "Fuel ethanol production: Process design trends and integration opportunities", *Bioresource Technology*; vol. 98; pp. 2415-2457
- Coelho S.T., Goldemberg J., Lucon O., Guardabassi P. (2006) "Brazilian sugarcane ethanol: lessons learned", *Energy for Sustainable Development*; vol. X; no. 2; pp. 26-39
- David P.A., Bunn, J.A. (1988) "The economics of gateway technologies and network evolution: Lessons from Electricity Supply History", *Information Economics and Policy*; vol. 3; pp. 165-202
- Demirbas A. (2007) "Progress and recent trends in biofuels", *Progress in Energy and Combustion Science*; vol. 33; pp. 1-18
- Domac J., Richards K., Risovic S. (2005) "Socio-economic drivers in implementing bioenergy projects", *Biomass and Bioenergy*; vol. 28; pp. 97-106
- Dosi G. (1982) "Technological Paradigms and Technological Trajectories: A Suggested Interpretation of the Determinants and Directions of Technical Change", *Research Policy*; vol. 11; no. 3; pp. 147-162
- Drift (2006) *Transities & Transitie management: Een inleiding*, Dutch Research Institute for Transitions, Rotterdam
- Duffield J.A., Collins K. (2006) "Evolution of renewable energy policy", *Choices*; vol. 21; no. 1; pp. 9-14
- EC/COM/265 (2005) "Green paper on energy efficiency or doing more with less", final, *European Commission*, Brussels

EC/COM (2006) *Biofuels in the European Union: An agricultural Perspective*, Fact Sheet, Office for Official Publications of the European Communities, Luxembourg, via: <http://europe.eu>

EC/IP/07/155 (2007) "Commission plans legislative framework to ensure the EU meets its target for cutting CO<sub>2</sub> emissions from cars", *European Commission*, Brussels

EC (2005) *European Energy and Transport: Trends to 2030 - update 2005*, publication was prepared by the Institute of Communication and Computer Systems of National Technical University of Athens, Office for Official Publications of the European Communities, Luxembourg

EIA/DOE (2000) *International Energy Outlook 2000*, Energy Information Administration, US Department of Energy, via: <http://www.eia.doe.gov/oiaf/ieo/index.html>

EIA/DOE (2007) "Ethanol – A Renewable Fuel", *Energy Information Administration*, via: <http://www.eia.doe.gov/kids/energyfacts/sources/renewable/ethanol.html>

Eldomiaty T.I., Choi C.J., Cheng P. (2007) "Intercultural relations in the European Union: Economic convergences versus social mobility", *The Social Science Journal*; vol. 44; pp. 167-171

Elzen B., Hoogma R., Schot J. (1996) "Mobiliteit met Toekomst: Naar een vraaggericht technologiebeleid", rapport voor Ministerie van Verkeer en Waterstaat, V&W, Den Haag

Elzen B., Wieczorek A. (2005) "Transitions towards sustainability through system innovation", *Technology Forecasting & Social Change*; vol. 72; pp. 651-661

EPA/ULSD (2007) United States Environmental Protection Agency, *Ultra-low Sulfur Diesel Fuel Regulation*, Washington

Ernst & Young (2006) "Biobrandstoffen steeds belangrijker in Rotterdamse haven", press release via: [http://www.ey.nl/?pag=788&nieuws\\_id=2722](http://www.ey.nl/?pag=788&nieuws_id=2722)

ESMAP (2006) "Potential for Biofuels for Transport in Developing Countries", Energy Sector Management Assistance Program, *Knowledge Exchange Series*; vol. 4; pp.1-4

EU Biofuels Directive (2003) Directive 2003/30/EC, Official Journal of the European Union, English version, via: [http://ec.europa.eu/energy/res/legislation/doc/biofuels/en\\_final.pdf](http://ec.europa.eu/energy/res/legislation/doc/biofuels/en_final.pdf)

F.O. Lichts (2004) World Ethanol and Biofuels Report, via: <http://www.agra-net.com>

F&F/PoR (2007) *Facts and Figures on Rotterdam's oil and chemical industry*, Commercial Division, via: <http://www.portofrotterdam.com>

Faaij A.P.C., Domac J. (2006) "Emerging international bio-energy markets and opportunities for socio-economic development", *Energy for Sustainable Development*; vol. X; no. 1; pp. 7-19

Farrell J., Saloner G. (1986) "Installed base and compatibility: innovation, product preannouncements, and predation" *American Economist review*; vol. 76; pp. 940-955

Frambach R.T. (1993) "An Integrated Model of Organizational Adoption and Diffusion of Innovations", *European Journal of Marketing*; vol. 27; no. 5; pp. 22-41

Friedl B., Steininger K.W. (2002) "Environmentally Sustainable Transport: Definition and Long-Term Economic Impacts for Austria", *Empirica*; vol. 29; no. 2; pp. 163-180

Garrison R.H., Noreen E.W., Seal W. (2003) *Management Accounting*, European Edition, McGraw-Hill Education, Berkshire

Gave (2003) *Biofuels in the Dutch market: a fact-finding study*, Netherlands Agency for Energy and the Environment (NOVEM), Utrecht

Geels F.W. (2005) *Technological Transitions and System Innovations: A Co-Evolutionary and Socio-Technical Analysis*, Edward Elgar, Cheltenham, Northampton

Geels F.W. (2002) *Understanding the dynamics of technological transitions: A co-evolutionary and socio-technical analysis*, proefschrift, Twente University Press, Enschede

Geels F.W., Kemp R. (2000) *Transities vanuit sociotechnisch perspectief*, report for "Transities en Transitie management" from ICIS and MERIT, UT, Enschede en MERIT Maastricht

- Golbeck J. (2002) "Evolving Strategies for the Prisoner's Dilemma", *Advances in Intelligent Systems, Fuzzy Systems, and Evolutionary Computation*; February; pp. 299-306
- Hamel G., Prahalad C.K. (1994) *Competing for the future*, Harvard Business School Press, Boston
- Hansson J., Berndes G., Börjesson P. (2006) "The prospects for large-scale import of biomass and biofuels into Sweden – a review of critical issues", *Energy for Sustainable Development*; vol. X; no. 1; pp. 82-93
- Haynes K.E., Gifford J.L., Pelletiere D. (2005) "Sustainable transportation institutions and regional evolution: Global and local perspectives", *Journal of Transport Geography*; vol. 13; pp. 207-221
- Hekker M., van den Hoed R. (2004) "Competing Technologies and the Struggle towards a New Dominant Design: The Emergence of the Hybrid Vehicle at the Expense of the Fuel Cell Vehicle", *Greener Management International*; vol. 47; pp. 29-43
- Hendry C., Harborne P., Brown J. (2006) "Niche entry as a route to mainstream innovation: learning from the phosphoric acid fuel cell on stationary power", *Technology Analysis and Strategic Management*, (revised manuscript)
- Hisschemöller M., Bode R., van de Kerkhof M. (2006) "What governs the transition to a sustainable hydrogen economy? Articulating the relationship between technologies and political institutions", *Energy Policy*; vol. 34; pp. 1227-1235
- Hoekstra H.A., van Sluijs E. (2003) *Management van competenties: het realiseren van HRM*, Koninklijke Van Gorcum, Assen
- IEA/OECD (2004) *Biofuels for Transport: An International Perspective*, International Energy Agency, Chirat, Paris
- IEA/T40 (2006) "Sustainable International Bioenergy Trade: Securing and Demand", by IEA Bioenergy Task 40, *Copernicus Institute*, Utrecht
- IFQC (2002) "Overview of leaded gasoline and sulfur levels in gasoline and diesel", International Fuel Quality Center, via: <http://www.ifqc.org>
- Jobber D., Fahy J (2003) *Foundations of Marketing*, McGraw-Hill Education Ltd., New York
- Kemp R. (1994) "Technology and the transition to environmental sustainability: The problem of technological regime shifts", *Futures*; vol. 26; no. 10; pp. 1023-1046
- Kemp R., Schot J., Hoogma R. (1998) "Regime Shifts to Sustainability Through Processes of Niche Formation: The Approach of Strategic Niche Management", *Technology Analysis & Strategic Management*; vol. 10; no. 2; pp.175-195
- Kemp R., van den Bosch, S. (2006) *Transitie-experimenten: Praktijkexperimenten met de potentie om bij te dragen aan transitie*, Drukkerij NIVO, Delft
- Korbitz W. (2002) "New Trends in Developing Biodiesel World-wide", *Austrian Biofuels Institute*, via: [http://www.nachhaltigkeitsrat.de/service/download\\_e/pdf/asia\\_biofuels\\_worldwide.pdf](http://www.nachhaltigkeitsrat.de/service/download_e/pdf/asia_biofuels_worldwide.pdf)
- Kovarik B. (1998) "Henry Ford, C. F. Kettering and the fuel of the future", *Automotive History Review*; vol. 32; pp. 7-27
- Knothe G. (2001) "Historical Perspectives on Vegetable Oil-based Diesel Fuels", *Inform*; vol. 12; pp. 1103-1107
- Krush B. (1994) *The prisoners' dilemma*, A Public Domain Work, via: <http://www.krusch.com>
- Lamarck J.B. (1809) *Zoological Philosophy: An Exposition with Regard to the Natural History of Animals*, Paris
- Lamers P. (2006) *Emerging liquid biofuel markets: A donde va la Argentina?*, iiee publications, Lund, Sweden
- Lewis E. (1994) *Introduction to reliability engineering*, 2<sup>nd</sup> edition, John Wiley & Sons, U.S.
- Lienin S.F., Kasimir B., Stulz R., Wokaun A. (2005) "Partnerships for sustainable mobility: the pilot region of Basel", *Environment*; vol. 47; no.3; pp. 22-35
- Long B.L. (1997) "Environmental regulation: The third generation", Organisation for Economic Cooperation and Development, *The OECD Observer*; vol. 206; pp. 14-18
- Looker D. (2006) "Ethanol is trendy yet ancient: Burning grain alcohol for fuel is older than you might think", *Successful Farming Business Editor*; pp. 1-2

- Loorbach D. (2002) *Transition Management: governance for sustainability*, Berlin
- Loorbach D., Rotmans J. (2005) *Managing transitions for sustainable development, in Industrial Transformation – disciplinary approaches towards transformation research*, edited by A. J. Wieczorek and X. Olshoorn, Kluwer Academic Publishers, Dordrecht
- Macharzina K. (1999) “Limits of globalization”, *Management International Review*; vol. 39; no. 2; pp. 99-102
- MacLean H.L., Lave L.B. (2003) “Evaluating automobile fuel/propulsion system technologies”, *Progress in Energy and Combustion Science*; vol. 29; pp. 1-69
- McCormick K., Kåberger T. (2007) “Key barriers for bioenergy in Europe: Economic conditions, know-how and institutional capacity, and supply chain co-ordination”, *Biomass and Bioenergy*; vol. 31; pp. 443-452
- Metcalfe J.S. (2007) *The Broken Thread: Marshall, Schumpeter and Hayek on the Evolution of Capitalism*, first draft, ESRC centre for research on innovation and competition, University of Manchester, via: <http://www.lib.hit-u.ac.jp/service/tenji/amjas/Metcalfe.pdf>
- Mom G.P.A. (1997) *Geschiedenis van de auto van morgen*, proefschrift, Kluwer Bedrijfsinformatie, Deventer
- Mom G.P.A. (2003) “Conceptualizing technical change: alternative interaction in the evolution of the automobile”, *Artefacts series: studies in the history of science and technology*; vol. 3; pp. 9-46
- Mom G.P.A. (2004) “Inter-artifactual Technology Transfer: Road Building Technology in the Netherlands and the Competition Between Bricks, Macadam, Asphalt and Concrete”, *History and Technology*; vol. 20; no. 1; pp. 75-96
- Nakicenovic N. (1986) “The Automobile Road to Technological Change: Diffusion of the Automobile as a Process of Technological Substitution”, *Technological Forecasting and Social Change*; vol. 29; pp. 309-340
- Nicolas J.-P., Pochet P., Poinboeuf H. (2003) “Towards sustainable mobility: application to the Lyons conurbation”, *Transport Policy*; vol. 10; pp. 197-208
- Noteboom B. (1989) “Diffusion, Uncertainty and Firm Size”, *International Journal of Research in Marketing*; vol. 6; pp. 109-128
- OICA (2002) “Sustainable development: the contribution by the automotive industry”, Organisation Internationale des Constructeurs d’Automobiles, via: <http://www.oica.net>
- O’Riordan T., Voisey H. (1998) *The Transition to Sustainability: The Politics of Agenda 21 in Europe*, Earthscan Publications, London
- Placet M., Anderson R., Fowler M.F. (2005) “Strategies for Sustainability”, *Research Technology Management*; vol. 48; no. 5; pp. 32-41
- PoR/YCPC (2006) *Port of Rotterdam: Your chemical port of choice*, ICIS Publication, via: <http://www.portofrotterdam.com>
- Policy with Citizens Program (2005) *VROM programma Beleid met Burgers: Aansluiten bij wat mensen beweegt*, Ministerie van VROM, Den Haag
- Ramesohl S., Merten F. (2006) “Energy system aspects of hydrogen as an alternative fuel in transport”, *Energy Policy*; vol. 34; pp. 1251-1259
- Raven R.J.P.M. (2005) *Strategic niche management for biomass: A comparative study on the experimental introduction of bioenergy technologies in the Netherlands and Denmark*, proefschrift, Eindhoven University Press, Eindhoven
- Raven R.J.P.M. (2007) “Niche accumulation and hybridization strategies in transition processes towards a sustainable energy system: An assessment of differences and pitfalls”, *Energy Policy*; vol. 35; pp. 2390-2400
- Read P. (2003) “The Policy, Economic, Environmental, and Social Aspects of Linking Bioenergy with Carbon Storage in a Sequential Decision Approach to the Threat of Abrupt Climate Change”, *OECD, Workshop on Biomass and Agriculture*, June 10-13, Vienna
- Reddy S., Painuly J.P. (2004) “Diffusion of renewable energy technologies – barriers and stakeholders’ perspectives”, *Renewable Energy*; vol. 29; pp. 1431-1447

- Refocus (2006) "Biofuelling Brazil: An Overview of the Bioethanol Success Story in Brazil", *Refocus*, May/June, Elsevier Ltd.
- Rip A., Kemp R. (1998) "Technological change", in: Rayner S., Malone E., *Human Choices and Climate Change*, Columbus, Ohio
- Rogers E.M. (1983) *Diffusion of Innovations*, third edition, The Free Press, New York
- Roos, A., Graham, R.L., Hektor, B., Rakos, C. (1999) "Critical factors to bioenergy implementations", *Biomass and Bioenergy*; vol. 17; pp. 113-126
- Rotmans J., Kemp R., van Asselt M., Geels F., Verbong G., Molendijk M. (2000) *Transities & Transitie management. De casus van een emissiearme energievoorziening*, report for the study "Transities en Transitie management", ICIS & MERIT, Maastricht
- Rotmans J. (2005) *Maatschappelijke innovatie: tussen droom en werkelijkheid staat complexiteit*, Brummelkamp Hoofddorp, Utrecht
- Rotmans J. (2007) *Duurzaamheid: van onderstroom naar draagwiel, op de rand van een doorbraak*, Jansen en van Driel, Rotterdam
- Rotmans R., Kemp R., van Asselt M. (2001) "More evolution than revolution: Transition management in public policy", *Foresight*; vol. 3; no. 1
- Rosillo-Calle F., Walter A. (2006) "Global market for bioethanol: historical trends and future prospects", *Energy for Sustainable Development*; vol. X; no. 1; pp. 20-32
- Ryan L., Convery F., Ferreira S. (2006) "Stimulating the use of biofuels in the European Union: Implications for climate change policy", *Energy Policy*; vol. 34; pp. 3184-3194
- Sagasti F.S., Sachs-Jeantet C. (1994) *The uncertain quest: science, technology, and development*, United Nations University Press, Tokyo
- SenterNovem (2007) A variety of informative articles, reports, and descriptions from <http://www.senternovem.nl>
- Sixth Framework Programme (2005) *Alternative Motor Fuels: Biofuel Cities*, Integrated Project, 'Description of Work' for BioEthanol for Sustainable Transport (BEST)
- Smith A., Stirling A., Berkhout F. (2005) "The governance of sustainable socio-technical transitions", *Research Policy*; vol. 34; pp. 1491-1510
- Smith P.G., Reinertsen D.G. (1998) *Developing Products in Half the Time*, second edition, John Wiley & Sons, New York
- SMP (2004) Sustainable Mobility Project, World Business Council for Sustainable Development, press-release July 5<sup>th</sup> 2004
- Solomon B.D., Barnes J.R., Halvorsen K.E. (2007) "Grain and cellulosic ethanol: History, economics, and energy policy", *Biomass and Bioenergy*; vol. 31; pp. 416-425
- Steenberghen T., López E. (2007) "Overcoming barriers to the implementation of alternative fuels for road transport in Europe", article in press, *Journal of Cleaner Production*; vol. xx; pp. 1-14
- TaskForce (2006) *Criteria voor duurzame biomassa productie*, eindrapport van de projectgroep 'Duurzame productie van biomassa', *Task Force Energietransitie*, via: <http://www.senternovem.nl>
- TaskForce (2007) *Toetsingskader voor duurzame biomassa productie*, eindrapport van de projectgroep 'Duurzame productie van biomassa', *Task Force Energietransitie*, via: <http://www.senternovem.nl>
- Thuijl E., Deurwaarder E.P. (2006) *European biofuel policies in retrospect*, Energy Research Centre of the Netherlands, Den Helder
- Tolan S., Berzon A. (2005) "Global Warming: What's Known vs. What's Told", *Nieman Reports*; vol. 59; no. 4; pp. 91
- Tokuda T. (1995) "Automobiles for sustainable mobility", *JSAE Review*; vol. 16; 341-348
- Tukker A., Butter M. (2007) "Governance of sustainable transitions: about the 4(0) ways to change the world", *Journal of Cleaner Production*; vol. 15; 94-103

- Turton H. (2006) "Sustainable global automobile transport in the 21<sup>st</sup> century: An integrated scenario analysis", *Technological Forecasting & Social Change*; vol. 73; pp. 607-629
- Tzeng G.H., Lin C.W., Opricovic S. (2005) "Multi-criteria analysis of alternative-fuel buses for public transportation", *Energy Policy*; vol. 33; pp. 1373-1383
- UN (2000) *The UN Millennium Summit 2000 report: We the peoples: the role of the united nations in the 21<sup>st</sup> century*, Department of Public Information, via: <http://www.un.org/millennium/sg/report>
- UN/DESA (2005) "Increasing Global Renewable Energy Market Share: recent perspectives and trends", The United Nations Department of Economic and Social Affairs, prepared for Beijing International Renewable Energy Conference 2005
- UNDP (2005) "Energy as an Instrument for Socio-Economic Development", United Nations Development Programme, via: [http://www.undp.org/seed/eap/html/publications/1995/1995a\\_ch10.htm](http://www.undp.org/seed/eap/html/publications/1995/1995a_ch10.htm).
- USDA/EU (2003) "EU: Biodiesel Industry Expanding Use of Oilseeds", via: <http://www.fas.usda.gov/pecad/highlights/2003/09/biodiesel3/index.htm> 10/
- USDA/DOE (2005) *Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply*, U.S. Department of Agriculture and the U.S. Department of Energy, Springfield
- Van de Kerkhof M., Wieczorek A. (2005) "Learning and stakeholder participation in transition processes towards sustainability: Methodological considerations", *Technological Forecasting & Social Change*; vol. 72; pp. 733-747
- Verbong G. (2000) *De Nederlandse overheid en energietransities: Een historisch perspectief*, Eindhoven: Stichting Historie der Techniek
- Vergragt P.J. (2004) "Transition Management for Sustainable Personal Mobility: The Case of Hydrogen Fuel Cells", *Greener Management International*; vol. 47; pp.13-27
- Vergragt P.J., Brown H.S. (2007) "Sustainable mobility: from technological innovation to societal learning", *Journal of Cleaner Production*; vol. 15; pp. 1104-1115
- VROMraad (2004) *Energietransitie: Klimaat voor Nieuwe Kansen*, beknopte versie, Gezamenlijk advies van de Vrom-raad en de algemene Energieraad, Van Deventer, 's-Gravenzande
- WBCSD (2001) *Mobility 2001: World mobility at the end of the twentieth century and its sustainability*, full Report, World Business Council for Sustainable Development, Conches-Geneva, Switzerland
- WBCSD (2004) *Mobility 2030: Meeting the challenges to sustainability*, full Report, World Business Council for Sustainable Development, Conches-Geneva, Switzerland
- WEO (2005) *World Energy Outlook 2005: Middle East and North Africa Insights*, International Energy Agency, via: <http://www.iea.org/textbase/nppdf/free/2005/weo2005.pdf>
- Whyte J. (2007) "Evolutionary Theories and Design Practices", Massachusetts Institute of Technology; *Design Issues*; vol. 23; no. 2; pp. 46-54
- Yokayo (2003) "A History of the Diesel Engine", *Yokayo Biofuels*, via: [http://www.ybiofuels.org/bio\\_fuels/history\\_biofuels.html](http://www.ybiofuels.org/bio_fuels/history_biofuels.html)
- Ziman J. (2000) "Evolutionary Models for Technological Change", in *Technological Innovations as an Evolutionary Process*, Cambridge University Press, Cambridge

## 7 Appendix A: The biofuels case-study

### 7.1 Introduction

To date, reducing transportation's contribution to local air pollution and global GHGs, and increasing energy supply security are primary goals convincing governments to identify and commercialize alternatives for dominant petroleum fuels like gasoline and diesel. Over the past two decades, several candidate fuels have emerged such as CNG, LPG, and electricity for electric vehicles. Although these fuels possess a number of benefits over traditional fuels, they also demonstrate drawbacks that limit their ability to capture a significant share of the market soon. They all require for instance costly modifications to vehicles, and the development of a separate fuel distribution and refueling infrastructure. As a result, both fuel suppliers and car manufacturers are reluctant to make the required investments in these highly uncertain markets.

In contrast, biofuels like ethanol and biodiesel have the potential to displace a substantial amount of traditional fuels around the world over the next few decades for various reasons.<sup>55</sup> Already at an oil price of 60 US dollars per barrel, it is a very attractive option to drive on biofuels instead of petroleum fuels.<sup>56</sup> Since biofuels (in low blend ratios) are compatible with current drivetrain technologies and can use existing distribution infrastructures, investment costs are surmountable. Consequently, they are able to leapfrog traditional market introduction barriers. Additionally, the use of these fuels dates back to over 100 years. Throughout that history, worldwide biofuel production has had many peaks and valleys. Each time production rose or fell, it responded to complex combinations of changes in demand, economical and political interests, and more recently environmental issues. Unfortunately, the term 'biofuel' is for many relatively unknown and, compared to fossil-based petroleum fuels, the use of biofuels for road transportation is still quite low in nearly every country.<sup>57</sup> In sum, it appears that biofuels' opportunities are enormous, but virtually untapped.

This case-study presents a basic understanding of biofuels for road transport, the production process of biodiesel and ethanol from different feedstock materials, and their future potential. Furthermore, an elaborated historical retrospection clarifies the different interrelated reasons for the employment of biofuels over time, and in different regions across the world. Finally, their potential benefits and critical issues are discussed to complete the picture around biofuels. A few things are closer explained by facts and figures. The main aim is to provide a basis for the investigation whether strategic market introduction lessons could be learned from past biofuels' experiences, current research activities, critical issues, and future prospects related to biodiesel and ethanol in particular. These 'lessons' and strategic directions are summarized in chapter 5, and represent the answer to research question 4, and a basis for the framework with recommendations for the biofuel value-chain. Finally, this case-study provides background knowledge for the elaboration of research question 2B in chapter 3.

---

<sup>55</sup> Using conservative estimates, at least a third of road transportation fuels worldwide could be displaced by biofuels in the 2050 to 2100 timeframe (EIA/OECD 2004).

<sup>56</sup> EU-produced biodiesel breaks even at oil prices around 60 US\$, ethanol becomes competitive at 90 US\$ (Deloitte 2006).

<sup>57</sup> Global market share of ethanol and biodiesel in 2003 was 2.8% and 0.2% respectively (F.O. Lichts 2004).



## 7.2 What are biofuels?

### 7.2.1 Biodiesel, feedstocks and process technology

The renewable-based biodiesel is a petroleum diesel substitute which until recently was produced and used almost solely in the EU, but is now gaining a foothold in other regions across the world (EC/COM 2006). The term ‘biodiesel’ generally refers to methyl esters (sometimes called fatty acid methyl esters, or FAME) made by a chemical transesterification process (EIA/OECD 2004). Biodiesel is fairly similar to petroleum diesel fuel and can be used in the same applications, but has somewhat different chemical, handling, and combustion characteristics. Biodiesel can be blended with conventional petroleum diesel in any fraction and used in compression ignition engines, as long as the fuel system that ‘consumes’ it is constructed of materials that are compatible with the blend. Common blends of biodiesel are 2%, 5%, and 20% (i.e., B2, B5, B20), and the ‘neat’ 100% form B100. Individual car and truck manufacturers determine which blend ratios are warranted for use in their engines. In general, B5 is permitted by all manufacturers. B20 to B100 is also frequently allowed (Gave 2003).<sup>58</sup> The properties of the biodiesel (e.g., cloud point, flash point, cetane number) depend on the type of feedstock and production process used.

#### Feedstock and production process technology

Predominant feedstocks for biodiesel production are soybean oil in the US, rapeseed and sunflower oil in Europe, and palm oil in Malaysia. Biodiesel can also be produced from a variety of other feedstocks including vegetable oils, tallow and animal fats, and restaurant waste such as cooking oil and grease (EIA/OECD 2004).

Biodiesel from FAME can be produced by a variety of transesterification technologies, though most processes follow a similar basic approach. The purpose of the transesterification process is to lower the viscosity of the oil, so that it can be used in regular diesel combustion engines (Demirbas 2007). First, the oil is filtered and pre-processed to remove water and contaminants. If free fatty acids are present, they can be removed or transformed into biodiesel using pre-treatment technologies. The pre-treated oils and fats are then mixed with an alcohol (usually methanol) and a catalyst (usually sodium or potassium hydroxide). The oil molecules (triglycerides) are broken apart and reformed into esters and glycerol, which are then separated from each other and purified. The resulting esters are biodiesel (IEA/AEO 2007). Compared with some of the technologies being developed to produce ethanol and other biofuels, the biodiesel production process involves well-established, quite simple, technologies that are not likely to change significantly in the future (USDA/EU 2003). The biofuel production process typically yields as co-products crushed bean ‘cake’ (an animal feed), and glycerin. Glycerin is a valuable chemical used for making many types of cosmetics, medicines, and foods, and its co-production improves the economics of making biodiesel (EIA/OECD 2004). However, although glycerin has economic value, representatives from the pharmaceutical industry have warned that the demand for glycerin is relatively inelastic, and if large amounts of glycerin are produced by an expanding biodiesel industry, it will push the price of glycerin down substantially (USDA/EU 2003), and thus reducing the overall profitability and competitive position of the biodiesel industry.

---

<sup>58</sup> For example in Volkswagen’s most recent diesel engines.

### **7.2.2 Ethanol, feedstocks and process technologies**

In the road transportation sector, ethanol is the most widely used liquid biofuel in the world, and can be applied as partial or complete replacement for gasoline. In the US, over 99% of all domestically produced ethanol fuel is blended into gasoline at up to 10% (E10, or 'gasohol') (EIA/DOE 2007). To date, all gasoline sold in Brazil contains at least 25% ethanol, and nearly all motor vehicles in Brazil can run on that mixture (Refocus 2006). The most frequent use of ethanol in the EU at present is through conversion into derivatives, such as ethyl tertiary butyl ether (ETBE) composed of a mixture of ethanol and fossil fuels (EC/COM 2006). Additionally, Sweden imports substantial amounts of ethanol to meet its demands as a result of the national sustainable development policy. Ethanol can be used as a 5% blend with gasoline under the EU quality standard EN 228, this blend requires no engine modification and is covered by vehicle warranties (Demirbas 2007). Ethanol mixtures are available up to 85%, but require then engine modification, i.e., the installation of flexible fuel technology. Furthermore, ethanol can be produced from a multitude of different biomass feedstock materials and by several conversion processes. A common characteristic is that the feedstocks first are converted into sugars, after which these sugars are converted through fermentation to alcohol, i.e., ethanol.

#### Feedstock and process technologies

Ethanol can be produced from any biological feedstock that contains abundant natural sugars or starch. Obvious feedstock examples include sugar cane (Brazil) and sugar beets (Europe). Starch containing cereals like maize, corn, wheat (often used in the US and Europe) are other examples that can be relatively easy converted into sugar. These however, require a slightly different conversion process. Lignocellulosic biomass materials including grasses, trees, and various waste products from agriculture and forestry, wood, pulp, paper processing facilities and municipal solid waste can also be converted to alcohol (IEA/OECD 2004). Considering its great availability and low costs, this type of feedstock is the most promising for the long-term. However, the conversion process is complex and large-scale commercial production of ethanol fuel from lignocellulosic materials has still not been implemented (Cardona & Sánchez 2007). Nevertheless, techniques are being developed and progress has been made to convert lignocellulosic materials to ethanol more effectively. Additionally, cellulose can also be gasified to produce a variety of gases (e.g., hydrogen) (IEA/OECD 2004). The key steps of the feedstock-to-ethanol conversion process for different feedstock materials is clarified in figure 17, and briefly discussed in the subsequent sub-sections.

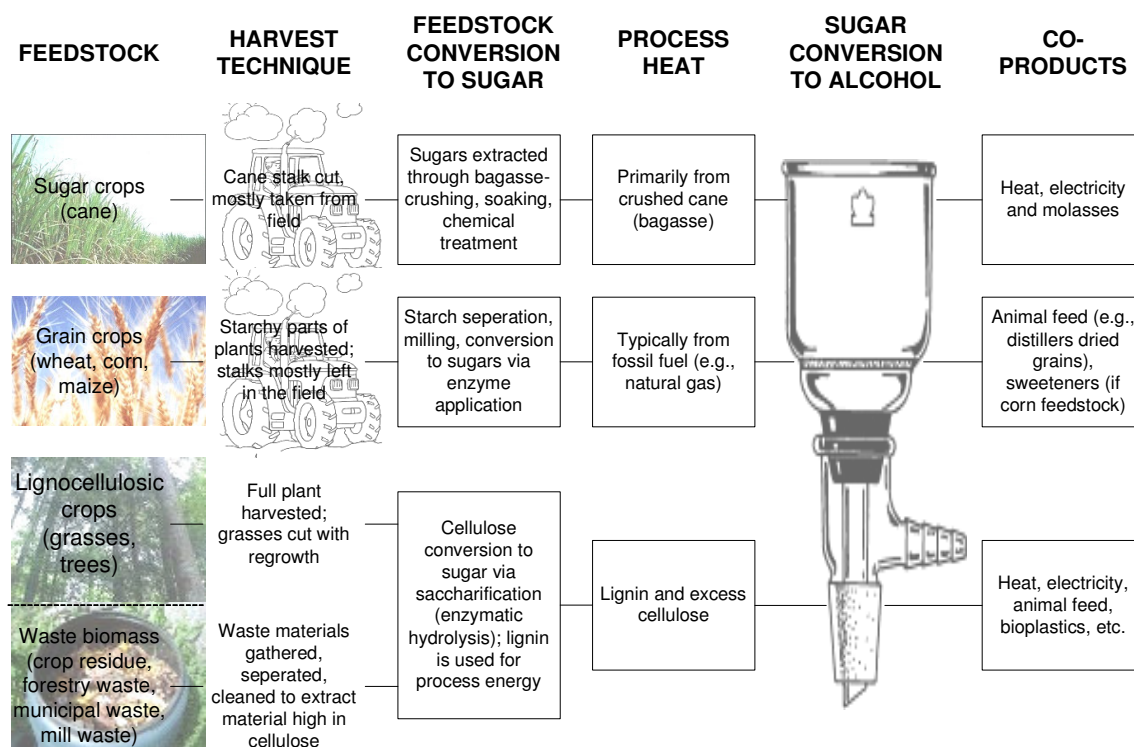


Figure 17: Ethanol production steps by feedstock type and conversion technique (source of text: IEA/OECD 2004)

Sugar cane-to-ethanol

The least complicated way to produce ethanol is to use sucrose-containing biomass that can be fermented directly to ethanol. The conversion of sucrose into ethanol is easier compared to starchy materials and lignocellulosic biomass because previous enzymatic hydrolysis of the feedstock is not required since the disaccharide can be broken down by the yeast cells, additionally, the conditioning of the molasses favors the hydrolysis of sucrose (Cardona & Sánchez 2007). In producing ethanol from sugar crops, the crops must first be processed to remove the sugar by for instance, crushing, soaking and chemical treatment. The sugar is then fermented to alcohol using yeasts and other microbes. A final step distills (purifies) the ethanol to the desired concentration and usually removes all water to produce anhydrous ethanol that can be blended with gasoline. In the sugar cane process, the crushed stalk of the plant, the bagasse, consisting of cellulose and lignin, can be used for process energy in the manufacturing of ethanol (IEA/OECD 2004). This is one reason why the fossil energy requirements and GHGs of sugar cane-to-ethanol processes are relatively low.

Grain-to-ethanol

In conventional grain-to-ethanol processes, only the starchy part of the crop plant is used. To produce ethanol from starch, it is necessary to break down the chains of this carbohydrate for obtaining glucose syrup, which can be converted into ethanol by yeasts (Cardona & Sánchez 2007). This type of feedstock (and mainly corn and wheat) is the most utilized for ethanol production in Europe and the US (Solomon, Barnes & Halvorsen 2007). The grain-to-ethanol production process starts by separating, cleaning and milling the starchy feedstock. Milling can be wet or dry, depending on whether the grain is soaked and broken down further either before the starch is converted to sugar

(wet) or during the conversion process (dry) (IEA/OECD 2004). In both cases, the starch is converted to sugar, typically using a high-temperature enzyme process. From this point on, the process is similar to that for sugar cane crops, where sugars are fermented to alcohol using yeasts and other microbes. Major co-products from the grain-to-ethanol process are for instance protein-rich animal feed, corn gluten meal and oil, and in some cases sweeteners, although this varies depending on the specific feedstock and process used (EIA/AEO 2007).

#### Lignocellulosic biomass-to-ethanol

As discussed before, ethanol derived from lignocellulosic biomass feedstocks is the most promising future option. As a result, a large amount of studies regarding this topic is being carried out around the world. According to estimations by USDA/DOE (2005), supply potential is possibly up to four times the potential of corn. In addition, it is considered as the main feedstock for ethanol production in the near future (Cardona & Sánchez 2007). There are several important benefits from developing a commercial viable lignocellulosic-ethanol process, i.e., (1) access to a much wider array of potential feedstock (including waste cellulosic materials and dedicated cellulosic crops such as grasses and trees), opening the door to much greater ethanol production levels, (2) greater avoidance of conflicts with land use for food and feed production, (3) a much greater displacement of fossil energy per liter of fuel, due to nearly completely biomass-powered systems, and (4) much lower net well-to-wheels GHGs than with grain-to-ethanol processes powered primarily by fossil-based fuels (IEA/OECD 2004). Obviously, for countries where the cultivation of energy crops is limited (e.g., in the Netherlands) or difficult, lignocellulosic materials are an attractive option for the production of biofuels.

Two key steps must occur to convert lignocellulosic material into ethanol. First, the cellulose and hemicellulose parts of the biomass material (30-70%) must be separated from the lignin parts, and broken down into sugars through a process called saccharification. The yielded sugars, however, are a complex mixture of five- and six-carbon sugars that provide a great challenge for complete fermentation into ethanol (IEA/OECD 2004). Second, these sugars must be fermented, like the foregoing processes, to become ethanol. The first step is a major challenge, and to date, a variety of thermal, chemical and biological processes are being developed by a number of research organizations (overseas mainly in Canada and the US, in the EU mainly in Denmark, Spain and Sweden) to carry out this saccharification step in an efficient and low-cost manner (EIA/AEO 2007; EC/COM 2006). One important difference between lignocellulosic and conventional (sugar and grain crop) ethanol production is the choice of fuel that drives the conversion process. This choice has important implications for the associated net energy balances and for net GHGs. Currently, in many grain-to-ethanol production processes in North America and Europe, virtually all process energy is provided by fossil-fuels inputs, such as natural gas used to power boilers and fermentation systems. For lignocellulosic-to-ethanol conversion, nearly all process energy is provided by the biomass itself, in particular the unused cellulosic and lignin parts of the materials being processed (Cardona & Sánchez 2007).

### **7.2.3 The challenge**

Encouragement of production and utilization of biofuels on a large-scale, whether for strategic or environmental reasons, has always been a dynamic and challenging process. Until now, biofuels for commercial uses have mainly been produced by processing agricultural energy crops using available technologies. In biofuels literature, these are often referred to as ‘first-generation biofuels’. The long-term challenge however is, to produce biofuels from diversified raw (waste) materials by using innovative, more advanced processes and technologies that are commercially viable, and for which the environmental and economic gains are expected to be even more positive. Also the effective (novel) uses of co-products can contribute to this. Obviously, lignocellulosic-processing of feedstock material as described before is a central example that fits into these believes. Biofuels stemming from such process are called ‘second-generation biofuels’.

Throughout history, there have always been demonstrable reasons for biofuels to be considered as relevant option as road transportation fuel. However, they have also been discouraged frequently last century. To date, they include energy supply security reasons, environmental concerns, foreign exchange savings, and socio-economic issues related to the rural sector (Demirbas 2007). Moreover, and irrespective of what type, there are also critical aspects that need to be considered when implementing biofuels at large-scale. The following sections elaborate on important potential gains, drawbacks, and critical issues related to biofuels. But first, a closer look is given to the historical developments of biodiesel and ethanol across the world, to discover past rationales for the application of biofuels.

## **7.3 Historical perspectives**

### **7.3.1 1900-1972**

#### Vegetable oils and biodiesel

Visitors of the Paris World Exhibition in 1900 saw for the first time what was going to be one of the most important inventions for the coming 20<sup>th</sup> century, the diesel engine. Its inventor, the Frenchman Rudolph Diesel, had been struggling for years to create an engine which would surpass the steam engine’s inefficiency. Diesel succeeded with the building of the first practical diesel engine in 1897, which he continued to refine before the coming of the exhibition. To fuel his creation, Diesel did not use what today is considered as diesel fuel. His engine ran on peanut oil. It was Diesel’s belief that vegetable-based fuels would be the fuel of the future: cheap and easy to access, allowing farmers and the common man a chance to compete with big business in the ability to generate power (Butler 2007). The French government’s rationale to be concerned with this type of fuel was to enable the employment of diesel engines in the remote African colonies where this fuel could be easily cultivated. As a result, the colonies could be supplied with power and industry from their own resources, without being compelled to buy and import coal or liquid fuel (Knothe 2001). The primary fuels to power the diesel engines used in factories, aboard ships and submarines were vegetable fuels, and in 1912 Diesel said: “the use of vegetable oils for engine fuels may seem insignificant today, but such oils may become in course of time as important as petroleum and the coal tar products of the

present time.”<sup>59</sup> However, during the 1920s (16 years before Mercedes introduced the first diesel engine-propelled car with Bosch’s innovative fuel injection system<sup>60</sup>), a transition from vegetable fuels to petroleum-derived diesel took place. At that time, diesel engine manufacturers modified their engines to enable the utilization of petroleum-based diesel, which had a much lower viscosity.<sup>61</sup> The petroleum industries were able to penetrate into the existing fuel markets because their fuel was much cheaper to collect and produce than the biomass-based alternatives. By means of superior price, availability, and government subsidies, petroleum diesel quickly became the fuel of choice for diesel engines in industrial settings, as well as for light- and heavy-duty vehicles. It was not long before diesel, as it is known today, had eliminated the use of vegetable-based fuels.

Despite the widespread exploitation of petroleum diesel fuels, interest in vegetable oils as fuel is reported in several (some colonial-rich) countries during the 1920s and 1930s. Belgium, France, Italy, the United Kingdom, Germany, Brazil, Argentina, Japan and China have been tested and used vegetable oils as diesel fuels during this time. However, operational problems were reported due to the high kinematic viscosity of vegetable oils compared to petroleum diesel fuel, which resulted in poor atomization of the fuel in the engine’s combustion chambers and ultimately results in operational and reliability problems, such as engine deposits. Attempts to overcome these problems included preheating of the vegetable oil, blending it with petroleum-derived diesel fuel or ethanol, pyrolysis and cracking of the oils.<sup>62</sup> Nevertheless, in the meantime, diesel engines were optimized for uses with cheap petroleum diesel instead of vegetable oils, ultimately reducing its viability strongly.

On August 31, 1937, G. Chavanne of the University of Brussels was granted a patent for a procedure for the transformation of vegetable oils for uses as fuels in compression ignition (diesel) engines (patent nr. 422,877). This patent described the alcoholysis (i.e., the transesterification) of vegetable oils using methanol and ethanol in order to separate the fatty acids from the glycerol by replacing the glycerol by short linear alcohols. This appears to be the first account of the production of what today is known as ‘biodiesel’. Through the transesterification, the originally vegetable oils turn into biofuels, from which the characteristics strongly correspond to petroleum diesel (Knothe 2001). Obviously, the great benefit is that standard diesel engines required only minor adjustments to run on biodiesel. In this case, the fuel was adapted to use in conventional engines (for that time). This confirms the complex interactions between both domains of technology, engines and fuels. During World War II, biodiesel served as emergency fuel due to the often limited supply of crude oil. As a result, this was the first relatively considerable scale application of biodiesel (Knothe 2001). Nevertheless, after the war large oil fields were discovered worldwide, and the supply of cheap oil got started again. The worldwide application of biodiesel was negligible until the first oil crisis in 1973.

### Ethanol

Already in the 1850s, ethanol was a major lighting fuel in the US. However, during Civil War, a liquor tax was placed on ethanol to raise money for the war. This tax increased the price of ethanol so much that it could no longer compete with other fuels. As a result, ethanol production declined

---

<sup>59</sup> Via: [http://www.biodieselamerica.org/what\\_is\\_biodiesel](http://www.biodieselamerica.org/what_is_biodiesel).

<sup>60</sup> Via: [http://www.bosch.de/innovationen\\_kfz/content/language2/html/diesel.htm](http://www.bosch.de/innovationen_kfz/content/language2/html/diesel.htm).

<sup>61</sup> The viscosity of vegetable oils is about an order of magnitude greater than petroleum-derived diesel fuels (Knothe 2001).

<sup>62</sup> Via: <http://www.mechanicalengineering.cc/mechanical-engineering-archives/186-Making-biodiesel,-how-to-make-biodiesel.html>.

sharply, and production levels did not begin to recover until the tax was repealed in 1906 (IEA/DOE 2007). In the early 1900s, ethanol fuel has been used on a large scale in Europe too, and in particular Germany, France, and Italy. Even so much, that in 1902 an exhibition was dedicated to alcohol fuels for uses in automobiles, farm machinery, lamps, stoves, heaters (Rosillo-Calle & Walter 2006). To give an idea about the widespread use, the production of ethanol fuel in Germany alone increased from about 38 million liters (MI) in 1887 to 98.5 MI in 1904 (Kovarik 1998). At that time, Diesel was not the only inventor to believe that biomass-based fuels would be the foundation for the transportation industry. Henry Ford designed his automobiles, beginning with the 1908 Ford Model T, to use ethanol. According to Ford Motor Company's historical files, Ford, who grew up on a farm, had a strong interest in chemistry and in using farm products to make fuels. He believed gasoline was on the way out, as he said in 1916: "Gasoline is going – alcohol is coming," Ford said. "It is coming to stay, too, for it's in unlimited supply. And we might as well get ready for it now. All the world is waiting for a substitute for gasoline. When that is gone, there will be no more gasoline, and long before that time, the price of gasoline will have risen to a point where it will be too expensive to burn as a motor fuel" (Looker 2006). Ford was so convinced that renewable resources were the key to the success of his automobiles, that he built a plant to make ethanol in the Midwest and formed a partnership with Standard Oil to sell it in their distributing stations (Yokayo 2003). Ford's biofuel turned out to be fairly popular, especially with farmers, and in the 1920s ethanol represented about 25% of Standard Oil's fuel sales in that part of the country. In retrospect Ford's alliance with Standard Oil may not have been such a good idea. As Standard Oil tightened its grip on the industry, it focused its attention on exploiting its petroleum markets and eliminating any competition.<sup>63</sup> The ongoing discoveries of large oilfields resulted in decreased oil prices and the growth of the petroleum fuels sector. In addition, when the US Prohibition<sup>64</sup> began in 1919, ethanol was banned because it was considered a liquor and could only be sold when mixed with petroleum (EIA/DOE 2007). In the US, the combination of raising taxes, a concerted campaign by major oil companies and the availability of cheap petroleum effectively killed off ethanol as a major transportation fuel in the early part of the 20<sup>th</sup> century (Rosillo-Calle & Walter 2006). During the first half of the 20<sup>th</sup> century, also several European countries saw periods of prohibition of alcoholic beverages. Nevertheless, after the First World War, interest in ethanol continued (e.g., from General Motors Corporation and DuPont) as both an anti-knock agent, i.e., octane enhancer, and as a possible replacement for petroleum fuels (Solomon, Barnes & Halvorsen 2007). For a while ethanol boosted octane, but it lost out that application to lead additives, in spite of some public health concerns (Looker 2006). In the mid 1930s, alcohol blended fuels enjoyed a brief resurgence as falling corn prices prompted US' Midwestern states to seek alternative uses for their farm products. Global interests for ethanol fuel temporarily rose during World War II, when oil and other resources were scarce.

Post war brought new cars and increased petroleum use. Nevertheless, despite its use during the war, biofuels remained in the obscurity compared to fossil fuels. Virtually no commercial ethanol was available and the fuel was only used for niche applications (e.g., racing, agriculture). The elimination of any potential competitor for petroleum-based fuels continued too. For instance, the

---

<sup>63</sup> Via: <http://www.chelseagreen.com/images/biodieselchap8.pdf>.

<sup>64</sup> The term 'Prohibition', also known as Dry Law, refers to a law in a country by which the manufacture, transportation, import, export, and sale of alcoholic beverages is restricted or illegal.

major oil industries quietly bought electric trolley car systems which were a major part of the transportation infrastructure system. They dismantled them, and sporadically replaced with diesel buses. These industries also pushed the government to build roads and highways, so the automobiles they produced had a place to operate. This newly created transportation infrastructure was built with public funds, supporting and aiding the growth and strength of the petroleum, automobile, and related industries. By the 1970s, Major parts of the world were dependent on foreign oil.<sup>65</sup>

### **7.3.2 1973-today**

#### Biodiesel

The oil crisis starting on October 17, 1973 was a rude awakening for most oil importing nations. As the price of oil increased dramatically and long lines at gasoline stations grew even longer, people across the world began to look for alternative sources of energy, the potential of biofuels reentered the public consciousness. Biodiesel began to make a comeback. In 1977, E. Parente, a Brazilian scientist, created the first biodiesel fuel which was classified by international norms, conferring a standardized identity and quality. The next research into biodiesel fuels began in South Africa and in by 1983, the process for producing qualified and engine-tested biodiesel was completed and published internationally (Butler 2007). To date, this chemical process is well-known, considered quite simple, and still widely applied for biodiesel production (USDA/EU 2003). Nevertheless, it was not until 1989 that the first industrial-scale plant for biodiesel fuel was established by the Austrian company Gaskoks, who had purchased the technology from the South African engineers (Butler 2007).

Throughout the 1990s, plants were opened in many European countries including France, Germany and Italy. The beginning of the large increases in biodiesel production in Europe was in 1993. Changes in the European Union's Common Agricultural Policy (CAP) established a set-aside<sup>66</sup> program whereby farmers were obligated not to grow food or feed crops on a portion of their arable crop land, however, they were allowed to plant rapeseed, sunflowers, or soybeans for industrial purposes (USDA/EU 2003). The production of vegetable oil on set-aside for use in producing biodiesel was clearly an option which led to a rapid growth of the European biodiesel industry. France launched local production of biodiesel fuel from rapeseed oil, which is often mixed into regular diesel fuel at a level of 5%, and used by some captive fleets (e.g. public transportation) at a level of 30%. Renault, Peugeot and other manufacturers have certified truck engines for use with up to that blend level of biodiesel, and experiments with 50% biodiesel are underway. In 1999, the Journey to Forever, a non-government organization, traveled from Hong Kong to Southern Africa teaching people of small villages along the road how to make their own biofuel for use in heaters, tractors, buses, automobiles, and other machines they might have. Under the motto "we have the opportunity and the resources to shed our dependence on foreign oil, if we choose" nations in other parts of the world also saw local production of biodiesel starting up.<sup>67</sup>

Another big boost for biodiesel, especially in Germany, came when vegetable oil prices were relatively low from early 1999 to mid 2002, and petroleum diesel prices varied, but on average were relatively high during this period. With biodiesel exempted from the mineral fuel tax, production

---

<sup>65</sup> Via: [http://www.ybiofuels.org/bio\\_fuels/history\\_biofuels.html](http://www.ybiofuels.org/bio_fuels/history_biofuels.html).

<sup>66</sup> Set-aside is land taken out of production to reduce the risk of food surpluses (via: [www.defra.gov.uk](http://www.defra.gov.uk)).

<sup>67</sup> Via: <http://journeytoforever.org/biodiesel.html>.



began to look very attractive and a large number of projects (often in collaboration with car manufacturers like VW) were initiated. Many independent fuelling stations in Germany, who had a pump available since leaded gasoline became prohibited, marketed the biodiesel under favorable conditions. In 2004, a new tax policy in Germany, allowing full tax exemption for biofuels blended with fossil-based fuels, made oil companies to start blending biodiesel up to 5%. As a result, over 1900 fuelling stations in Germany offer biodiesel for their customers. (Thuijl & Deurwaarder 2006). The French industry also benefited from low vegetable oil prices, but the amount of biodiesel receiving a reduced motor fuel tax was, and still is, limited according to the rules of the French program (USDA/EU 2003). In sum, biodiesel is available at many fuelling stations across Europe.

Although biodiesel use from the 1990s onwards is primarily in Europe, it is beginning to be seen more and more in the US. Unlike the European biodiesel industry, which is largely a creation of national-government-sponsored research and energy policies, and much focused on rapeseed, the biodiesel industry in the US has its strongest support from Midwestern soybean farmers. The US is the largest producer, consumer, and exporter of soybeans in the world, with an average annual production of about 70 million tons. Because the demand for soy meal has generally risen faster than the demand for soy oil for many years, the soybean industry has been faced with the dilemma of what to do with the surplus oil. Much of this surplus has been directed toward the biodiesel market, especially in recent years.<sup>68</sup> As a result, the Energy Policy Act (EPA) was amended by the Energy Conservation Reauthorization Act of 1998 to include biodiesel fuel use as a way for federal, state, and public utility fleets to meet requirements for using alternative fuels. As a result, pure biodiesel (B100) is now considered an alternative fuel under EPA. That amendment started the sharp increase in the number of biodiesel users, which now include the US Postal Service and the US Departments of Defense, Energy, and Agriculture. Furthermore, countless school districts, transit authorities, public utility companies, and garbage and recycling companies also use the fuel.<sup>69</sup> In 2005, the state of Minnesota passed a law which made it mandatory that all diesel fuels sold in the state must contain at least 2% biodiesel. Over 100 years after Rudolph Diesel first created his engine, the world is coming back in line with his dream of vegetable oil-based fuels (Butler 2007).

### Brazilian ethanol

The ethanol fuel market revived in the 1970s primarily in Brazil and the US. Compared to both, the size of the European ethanol market is diminutive and therefore not discussed in this sub-section.<sup>70</sup> Brazil developed the sugarcane-based Proalcool Program in 1975 in response to the 1973 Middle East OPEC oil embargo, and the desire to reduce dependency on foreign oil. With help of public subsidies and tax breaks, farmers planted more sugar cane, investors built distilleries to convert the sugar to ethanol, and car manufacturers designed cars to run on E95.<sup>71</sup> The government financed a huge distribution network to get the fuel to gasoline stations and kept ethanol prices low to attract consumers (Refocus 2006). The policy was very successful, and in the mid 1980s Brazil was the only country mass-producing ethanol for motor vehicles. In the late 1980s, over half of the cars in Brazil

---

<sup>68</sup> Via: <http://www.chelseagreen.com/images/biodieselchap8.pdf>.

<sup>69</sup> Via: [http://www.eere.energy.gov/afdc/altfuel/bio\\_market.html](http://www.eere.energy.gov/afdc/altfuel/bio_market.html).

<sup>70</sup> Except Sweden which had a considerable growth in ethanol fuel use in the past five years, as a result of the government's strategy for long-term sustainable development. Sweden is currently importing ethanol at large-scale.

<sup>71</sup> Globally, 85% ethanol blend in gasoline is considered as maximum, however, the Brazilian climate allows the use of E95 in FFVs without negatively affecting them.

ran on E95. Though a late 1980s sugar shortage and price hikes made the ethanol subsidy too costly for the government. Additionally, the national oil company, Petrobras, had discovered new offshore oil fields, making Brazil more self-sufficient in oil. As a result, market share of FFVs reduced to where it is today, at 20%. Ethanol production in Brazil was at its lowest in 1993 (fig 18). Still, all of the gasoline sold in Brazil to date must contain at least 25% ethanol. According to ESMAP (2006), ethanol currently accounts for more than 40% of Brazil's total gasoline-ethanol market, and receives still tax benefits compared to gasoline to ensure its share.

From 2003 onwards, the Brazilian ethanol market revived again due to a combination of strong policy and market forces. First, a new generation of FFVs entered production in Brazil in 2003. The second important factor was that the national oil company Petrobras had complete control over oil in Brazil and was in a position to dictate policy, a policy which ensured that the consumer could decide what fuel mix was the most economical to use. A third important factor was the international market for alcohol. In 2004, there was a significant change in the foreign market. In that year, a total of 14.7 billion liters of alcohol was produced. About 2.4 billion liters was exported, compared with 1.2 billion liters in 2003, generating 500 million US dollars in revenue. This increase was mainly due to an increase in international demand of alcohol for use as fuel (Refocus 2006). To date, several countries have shown great interest in the Brazilian experience. The main importers of Brazilian ethanol are the US and India. The Brazilians are keen on opening up new markets, including the Chinese and Japanese markets. In sum, the Brazilian ethanol experience itself is an illustration of the fact that using ethanol for road transport is feasible, though involves complex socio-economic and logistical challenges, and heavy governmental support and involvement.

#### US ethanol

The US is the second large ethanol producer, and produces currently as much ethanol as Brazil. Compared to Brazil, the US ethanol industry is rebuilt more gradually, but started too as a response to the oil embargo. In 1974, the first of many legislative actions to promote ethanol as a fuel, the Solar Energy Research, Development, and Demonstration Act led to research and development projects of the conversion of cellulose and other organic materials including waste into useful energy or fuels. In 1975, the US started to phase out lead in gasoline which made ethanol attractive as a possible octane enhancer and volume extender (EIA/DOE 2007). However, MTBE (made from natural gas and petroleum) dominated this market over ethanol since it was cheaper to produce. The US Energy Tax Act (ETA) of 1978 officially defined gasohol as a blend of gasoline with at least 10% non-fossil fuel-based ethanol by volume. Furthermore, the ETA exempted ethanol from the excise tax on gasoline, which equaled 10.5 US dollar cents per liter subsidy for ethanol. After peaking at 15.8 cents in the mid to late 1980s, the excise tax exemption was reduced to 13.4 US dollar cents per liter of ethanol in 2005 (Solomon, Barnes & Halvorsen 2007).

In 1980, marketing of commercial ethanol-blended fuels began at Amoco Oil Company, followed by Ashland, Chevron, Beacon, and Texaco. At that time, about 1 billion US dollars went to biomass-related projects from the Interior and Related Agencies Appropriation Act. approximately 50 million gallons of ethanol per year were produced (EIA/DOE 2007), which was a major increase from the late 1950s until the late 1970s, when virtually no ethanol fuel was commercially available in the US. Several more tax benefits as well as loan and price guarantees were approved, to support ethanol producers and blenders. However, the growth of this industry was again hindered by very low

gasoline prices of the mid 1980s (Solomon, Barnes & Halvorsen 2007). As a result, 89 of the 163 commercial ethanol plants went out of business by the end of 1985, despite the subsidies (EIA/DOE 2007).

Until the late 1980s, the rationale of using ethanol instead of petroleum-derived gasoline was mostly to reduce dependency on foreign oil exporting nations, and to stimulate the national agricultural economy. In 1988 however, ethanol was first used as oxygenate in gasoline to reduce the environmental burden resulting from transportation activities. The US states of Denver and Colorado mandated oxygenated fuels (i.e., fuels containing oxygen) for winter use to control CO emissions (EIA/DOE 2007). Furthermore, in the private sector the production of alternative fuel vehicles was promoted by the Alternative Motor Fuels of Act of 1988, which provided car manufacturers with credits against their compliance requirements under the Corporate Average Fuel Economy (CAFE) standards for each FFV or alternative fuel vehicle they produced (EIA/AEO 2007). In reality however, the initiative had little effect on the use of alternative fuels since at that time few fuel retailers offered E85. For this reason, the program was frequently criticized as a mechanism for car manufacturers to avoid CAFE requirements while being ineffective at supporting purchases of E85 (Duffield & Collins 2006). The EPA of 1992 contributed to increased usage of ethanol blends by requiring specified (primarily government-owned) car fleets to begin purchasing alternative fuels and FFVs. This act provided also tax deductions for installing the equipment to dispense alternative fuels. Furthermore in 1992, the Clean Air Act Amendments mandated the winter-time use of oxygenated fuels in 39 major areas where EPA emissions standards for CO had not been met. However, the continued low gasoline prices in the early-mid 1990s, coupled with weak corn harvests and the doubling of corn prices, led several Midwestern states to approve new subsidies to keep the struggling ethanol industry solvent. In 1996 total ethanol production nonetheless declined back to the 1992 level (EIA/DOE 2007).

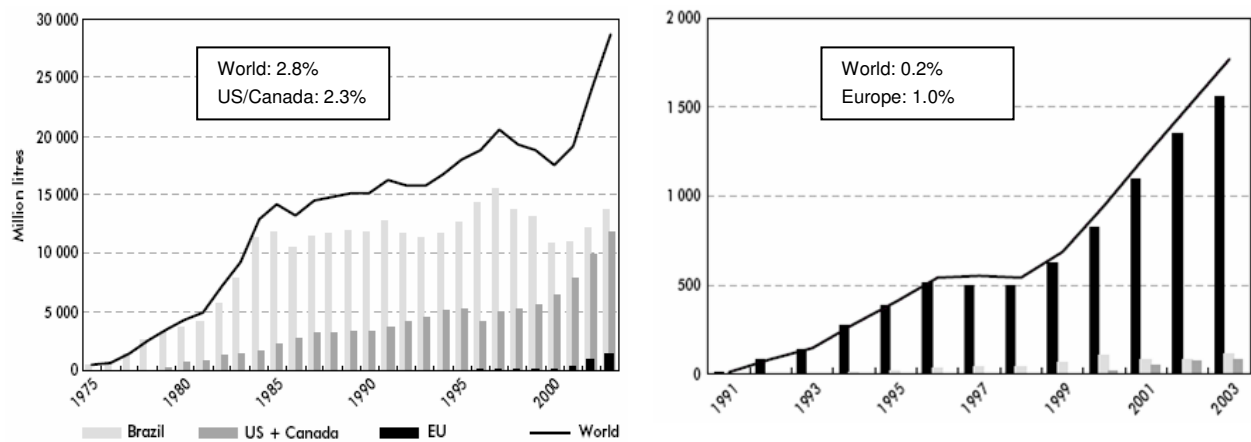
For the US ethanol industry past ten years had been far different. Ethanol production recovered, consolidated, and grew rapidly, with a total 2005 production that tripled 1997 output (Solomon, Barnes & Halvorsen 2007). The rapid growth in US ethanol production and use, especially since 2002, can be directly attributed to increasing restrictions on MTBE as oxygenate. The EPA namely recommended that MTBE should be phased out nationally (EIA/DOE 2007). The accelerated growth in the US ethanol production is expected to continue at least through 2012 because of the Renewable Fuel Standard approved under EPA. (Solomon, Barnes & Halvorsen 2007).

## **7.4 Biofuels global potential: benefits and critical issues**

### **7.4.1 Introduction**

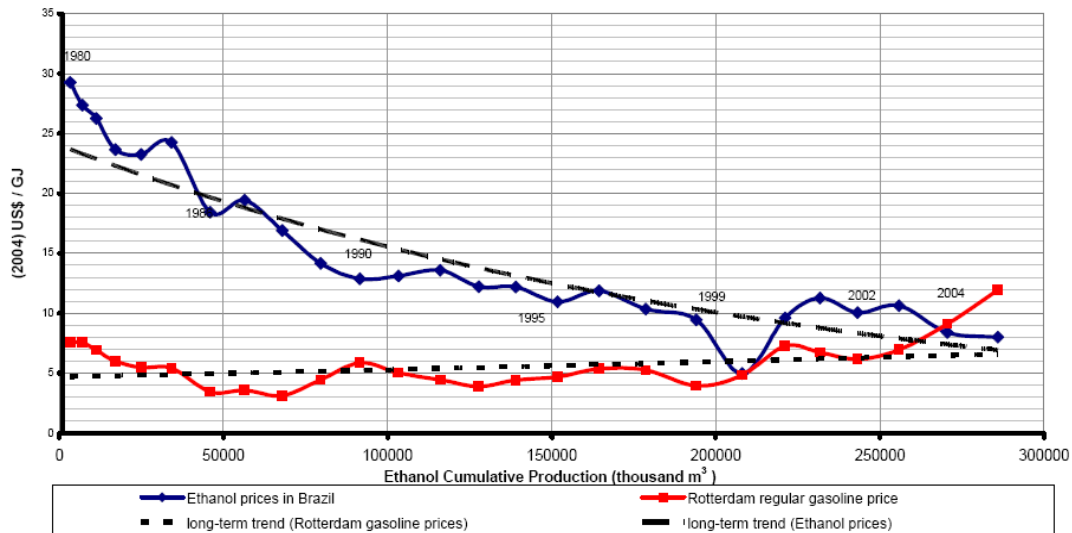
Clearly from the historical inspection, the past three to four decades have witnessed a growing interest on a global scale in biofuels as a substitute for petroleum fuels, due to a complex combination of factors including politics, environment, and socio-economics. As illustrated in figure 18, world ethanol and biodiesel production has increased significantly in recent years. In 2003, the market share of ethanol in world gasoline use amounted 2.8% (US & Canada: 2.3%), and of biodiesel amounted 0.2% (EU: 1.0%) (F.O. Lichts 2004). Besides the US and Brazil, more than 30 countries have already

introduced or are interested in introducing programs for ethanol and biodiesel fuel from some source (e.g., Australia, Germany, China, India, South Africa, Thailand) (Rosillo-Calle & Walter 2006). See also appendix E for their biofuel production potential and future plans.



**Figure 18: Worldwide and regional production of ethanol fuel (left, 1975-2003), and biodiesel (right, 1991-2003) (F.O. Lichts 2004 from IEA/OECD 2004 p.28 & 29)**

The production trends portrayed in figure 18 correspond with the historical post 1972 analysis portrayed in the previous section. Interestingly, the decreased and flattened worldwide production between 1996 and 2000 of ethanol and biodiesel respectively is, in all probability, the consequence of the exceptionally low (almost pre-oil embargo) price of fossil oil in that period (see also app. C), which then confirms the positive correlation between oil price and biofuels production. Furthermore, a clear steep trend from 2000 onwards in biofuels production is visible, which can be partially explained by the many US states switching from MTBE to ethanol as fuel oxygenate, the introduction of the new generation FFVs, and the increased global demand (all discussed in the previous section). Obviously, general explanations that make the relatively steep trend possible are the political support and the fact that biodiesel and ethanol have the potential to leapfrog traditional market introduction barriers. First, they are liquid fuels and possess the property to be well-compatible with current vehicles and blendable with dominant petroleum fuels. Additionally, they can share the long-established distribution infrastructure with only moderate modification of equipment. As a result, low-blend ethanol such as E10 is already dispensed in many fuelling stations worldwide with almost no incompatibility with materials and equipment. Biodiesel is currently blended with conventional diesel fuel in many industrialized countries, ranging from 5% in France to 20% in the US, and is used as a neat fuel in some trucks in Germany (IEA/OECD 2004). The increased investments made during the past two to three decades in biofuel production have clearly improved learning curve effects, i.e., price reductions (UN/DESA 2005; Coelho et al. 2006). Figure 19 illustrates a long-term comparison between ethanol prices in Brazil and Rotterdam conventional gasoline prices.



**Figure 19: Learning curve effect: long-term comparison ethanol prices in Brazil and regular gasoline prices in Rotterdam (UN/DESA 2005: p.14)**

Following the long-term trends of increasing gasoline prices and decreasing ethanol prices, it is plausible to state that sooner or later, the factor ‘price’ can be an important determinant in favor of ethanol. One important reason why the benefit-cost picture is likely to improve in the future is the ongoing development of advanced processes to produce biofuels with very low net GHGs. The following sub-sections discuss more in-depth important benefits and critical issues about biofuels and their potential large-scale applications.<sup>72</sup>

#### 7.4.2 Benefits

##### Reductions in oil demand

Biodiesel can be blended with petroleum-based diesel fuel in any ratio up to 100% for operation in conventional diesel engines. In addition, small amounts of ethanol can also be blended with diesel under certain conditions. Ethanol is easily blended up to 10% (on a volumetric basis) with modern conventional gasoline vehicles, and towards much higher levels (up to 85%) in vehicles equipped with the flexible fuel technology. Thus, biofuels can be applied directly without significant additional costs, replace petroleum fuels in today’s global vehicle fleet, and decline oil demands on a macro-level. Reductions are not 1:1 on a volumetric basis since biofuels have lower energy content (about 0.67 for ethanol), and additionally, some petroleum is regularly used to produce biofuels. In general, well-to-wheels studies indicate that it typically takes 0.15 to 0.20 liters of petroleum fuel to produce 1 liter of biofuel (with petroleum used to make fertilizers, to power farm equipment, to transport feedstock and to produce final fuels). The use of crops with low fertilizer requirements such as some grasses and trees (i.e., the lignocellulosic processes used to create second-generation biofuels), can improve this ratio.

<sup>72</sup> The discussion of benefits stems partially from IEA/OECD (2004) and EIA/AEO (2007), unless indicated differently.

### Reduction in GHGs, local pollution, and waste

On a well-to-wheels basis, the use of biodiesel and ethanol provides significant reductions in GHGs compared to gasoline and diesel fuel. The amount of CO<sub>2</sub> released during the burning of biofuels is absorbed from the atmosphere during crop growth. Hence, the CO<sub>2</sub> cycle maintains in balance. While a range of estimates exists, figure 20 shows that most studies reviewed by the International Energy Agency find significant net reductions in CO<sub>2</sub> emissions for both types of biofuels.

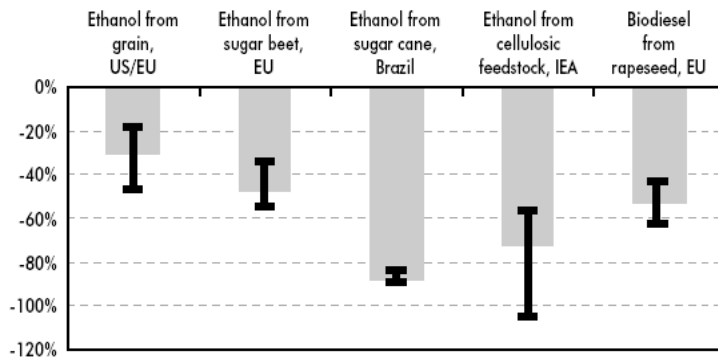


Figure 20: Range of estimated GHGs reduction from ethanol and biodiesel (IEA/OECD 2004: p.13)

Furthermore, the use of biofuels can reduce local air pollution resulting from transport-related activities. Air quality benefits are obtained when used either as pure, unblended fuels or, more commonly, when blended with petroleum fuels. Benefits include lower emissions of CO, SO<sub>2</sub>, and particulate matter. However, the use of biofuels can also lead to increases in some categories of emissions (e.g., NO<sub>x</sub> emissions). Unlike conventional petroleum fuels, biofuels are biodegradable and quickly break down into harmless, nontoxic substances if spilled.

### Waste reduction

In addition to the ‘standard’ environmental issues surrounding biofuels, such as their contribution to a reduction in GHGs and local air pollution, there are several other beneficial opportunities that are often overlooked. For instance, there is a clear benefit when biofuels are produced through recycling of waste products that would otherwise require being disposed. Both ethanol and biodiesel can be made from various (agricultural) waste products, i.e., crop and forestry residues, cooking oils, grease, and municipal wastes. In some cases, the waste product has an economic value, but often society must pay to remove and dispose the waste. If the waste product can be used to produce biofuels, then it provides an additional net benefit that may or may not be captured in the price of the biofuel. External costs, such as environmental impacts associated with disposing of waste, are normally not captured in the market price of biofuels. An interesting example is in Austria, where quality recycled frying oil was collected from 135 McDonald’s restaurants. One thousand tons were then transesterified into FAME of standardized quality (some have called that the McDiesel). Long-term bus trials in the daily routine traffic in the city of Graz have shown full satisfaction when using the McDonald’s-based 100% FAME (Korbitz, 2002). There are numerous pilot projects currently exploring this potential resource, including the city of Berkeley in California, which has begun operating recycling trucks on fuel made from recycled vegetable oil collected from local restaurants.<sup>73</sup>

<sup>73</sup> Via: [www.ecologycenter.org/recycling/biodiesel\\_pressrelease.pdf](http://www.ecologycenter.org/recycling/biodiesel_pressrelease.pdf).

### Vehicle performance benefits

Ethanol offers advantages over conventional gasoline. Ethanol's technical property of very high octane number (about 115), and the possibility to blend enables the function to increase the octane rating of petroleum gasoline. Octane rating is an indication of the fuel's ability to resist unwanted premature detonation (knocking) in the combustion chamber. Higher octane ratings correlate to higher activation energy, i.e., the amount of energy necessary to start a chemical reaction. Since higher octane fuels have higher activation energies, it is less likely that a given compression ratio will cause knocking. Using a fuel with a higher octane rating allows in turn the engine to run at a higher compression ratio, which is directly related to power. As a result, engines running on higher octane fuels usually deliver more power (Refocus 2006). Because of alcohol's higher octane rating and lower energy content, an engine powered by alcohol will perform on average the same as an engine running on gasoline. Although it is not the traditional first choice for octane enhancement (due to its relatively high cost), other options are increasingly out of favor (leaded fuel is now banned in most countries and MTBE is being discouraged or banned in an increasing number of countries). As a result, demand for ethanol for this purpose and as oxygenate is on the rise, e.g., in California. In Europe, ethanol is typically converted to ETBE before being blended with gasoline. ETBE provides high octane with even lower volatility than ethanol, though typically is only about half renewably derived.

Biodiesel has better lubricity characteristics than petroleum diesel. Consequently, it reduces engine wear due to the lower engine friction, even when blended (USDA/EU 2003). Furthermore, biodiesel can raise the cetane number and reducing the sulfur content (aiding fuel and vehicle performance). Table 11 compares the properties of biodiesel and conventional diesel, and confirms that biodiesel on virtually all properties scores better than petroleum diesel.<sup>74</sup>

**Table 11: Biodiesel-diesel property comparison (IEA/OECD 2004)**

Property	Biodiesel	Petroleum diesel (low sulphur)
Cetane number	51 to 62	44 to 49
Lubricity	+	Very low
Biodegradability	+	-
Toxicity	+	-
Oxygen	Up to 11%	Very low
Aromatics	0	18-22%
Sulphur	0	0-350 ppm
Cloud point	-	+
Flash point	150-205°C	52°C
Effect on natural, butyl rubber	Can degrade	No impact

### Agricultural and employment opportunities

Production of biofuels from crops such as corn and wheat for ethanol, and soy and rape for biodiesel provides an additional product market/distribution channel for farmers. Additionally, it can have a positive effect on labor employment and may bring additional economic benefits to rural communities (e.g., in developing regions). Brazil for instance, supports approximately 700,000 agricultural sector jobs in the ethanol industry. Furthermore, the Brazilian ethanol program has helped reverse migration to large urban areas and increases the overall quality of life in many small towns (UNDP 1995).

<sup>74</sup> Except for its effect on natural, butyl rubber.

Employment from the perspective of bioenergy systems covers different dimensions. First, direct employment refers to total labor necessary for crop production/waste collection, construction, operation and maintenance of conversion plant, and for transporting biomass. Indirect employment is jobs generated within the economy as a result of expenditures related to fuel cycles, and results from all activities connected, but not directly related (e.g., supporting industries, services). Especially in developing regions the higher purchasing power due to increased earnings from direct and indirect jobs, may also create opportunities for new secondary jobs, which may attract people to stay or even to move in. These latter effects are referred to as induced employment (Domac, Richards & Risovic 2005), obviously, all positive socio-economic benefits.

### 7.4.3 Critical issues

So far, the major benefits of using biofuels are discussed. However, as is the case with all alternative fuels, biofuels have critical issues that might seriously reduce its large-scale exploitation potential. This sub-section elaborates on important, not-ignorable aspects of biofuels. As a result, more deliberate strategic advice can be presented in favor of research question 4 and the framework.

#### Price

In developed countries, the production costs of ethanol and biodiesel is up to three times that of gasoline and diesel (IEA/OECD 2004). Additionally, these costs vary widely and depend on feedstock type, conversion process, size of production scale, region, etc. Although the production cost trend declines through learning effects (e.g., incremental technical improvements, optimizations) (fig. 19), and scale incensement of new conversion plants, it does not appear likely that first-generation biofuels (e.g., produced from grain or oil-seed feedstock) using conventional conversion processes are able to compete with gasoline and diesel in the short-term. However, in the long-term, when innovative processes are developed to produce second-generation biofuels under economic sound circumstances, and world oil prices have risen considerably, biofuels may come close to price-levels of petroleum-based fuels. Figure 21 provides best estimates by the International Energy Agency regarding near-term and long-term ranges of biofuels' production costs.

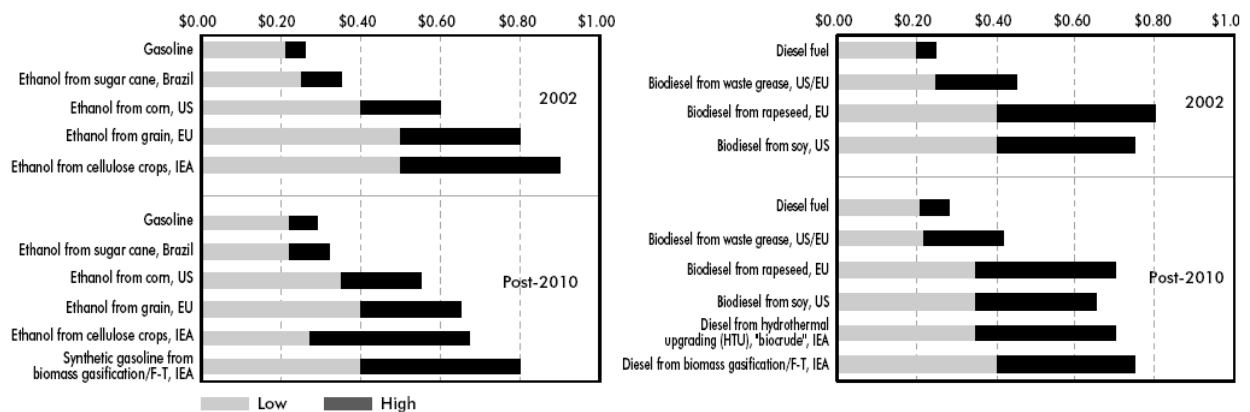


Figure 21: Cost ranges for ethanol and biodiesel production in US dollars per gasoline/diesel-equivalent liter (IEA/OECD 2004: p.85 & 86)



Clearly, on an energy basis, ethanol and biodiesel are currently more expensive to produce than gasoline and diesel in all regions considered. Only ethanol produced in Brazil, and biodiesel from rapeseed in Europe come cost-wise close to petroleum-based fuels. The estimation differences reflect the many variability factors at stake, such as scale, process efficiency, feedstock costs, capital and labor costs, and the co-product accounting.

Although to date, biofuels production costs determine largely retail prices (neglecting possible taxes/subsidies in some countries), transportation and distribution costs can be significant when feedstock material or biofuels must span great distances to reach (overseas) markets. On the other hand, the necessary engine modification costs (ranging from 0-150 US dollars, depending on biofuels' share) are practically negligible compared with the normal cost of a motor vehicle (Refocus 2006). Hence, these additional costs are not entitled as 'critical issue' in this case-study. Nevertheless, despite continuing improvements in biomass and biofuel production efficiencies and yields, the relatively high surrounded costs remain a critical issue to large-scale commercial biofuel deployment.

### Competition

Besides biofuels' direct costs, indirect costs affecting related markets should be considered as well. Production of biofuels from energy crops can drive the production of food crops away, and can increase their price which may translate into higher prices for consumers and unenthusiastic public attitudes against biofuels. The trade-off is complicated by extensive agricultural subsidies in many countries. As promoting biofuels rises on political agendas, agricultural policies have to be overlooked and take into account energy, environmental, and overall economic policies and priorities.

The potential global production of biofuels for transport is not yet well quantified. Recent studies reveal a wide range of long-term estimates of bioenergy production potential for all purposes including household energy use, electricity generation and transportation. Using conservative estimates, it appears that at least a third of road transportation fuels worldwide could be displaced by biofuels in the 2050 to 2100 timeframe. However, since biomass for transport fuels also compete with uses such as heat and electricity generation, it is not yet clear what the most cost-effective allocation for biomass is likely to be, and any estimates remain uncertain (IEA/OECD 2004). This uncertainty may result in a wait-and-see attitude and chicken-and-egg dilemma at political levels, obviously constraining a rapid growth of bioenergy applications.

The International Energy Agency assessed land requirements and land availability for producing biofuels. Scenarios developed for the European Union and United States indicate that near-term targets of up to 6% displacement of petroleum-based fuels with biofuels appear feasible using first-generation biofuels. A 5% displacement of gasoline in the EU requires about 5% of available cropland to produce ethanol, while in the US 8% is required. A 5% displacement of diesel requires 15% of European cropland, 13% in the US. Land requirements are greater primarily because average yields (liters of final fuel per hectare cropland) for biodiesel are considerably lower than for ethanol. Land requirements to achieve 5% displacement of both gasoline and diesel would require the combined land total, or 20% in the European Union and 21% in the US (IEA/OECD 2004).

### Trade schemes

Biomass feedstocks are mostly produced in developing regions with large surpluses (e.g., South America, East Asia), while demand would be mainly in developed regions where transport fuel

consumption is much higher. Currently, most transactions take place among a few countries and are based on bilateral agreements (Rosillo-Calle & Walter 2006). According to IEA/T40 (2006), many trade flows take increasingly place between neighboring countries. Current examples are export of ethanol from Brazil to Japan, EU and US, palm kernel shells from Malaysia to the Netherlands, and wood pallets from Canada to Sweden. In order to achieve large-scale intercontinental displacement of biomass and biofuels, robust trade schemes are required. Unfortunately, the international market for these goods is in its infancy, with no clear trade regimes. Many countries have different import tariffs for biomass and additional duties and taxes on liquid biofuels. For instance, in the EU most residues that contain starches are considered as potential animal fodder and are subjected to EU import levies. Rice residues containing 0-35% starch are taxed at 44 Euro/ton (i.e., about 3.1 Euro/GJ). For denaturized ethanol of 80% concentration and above, the import levy is 102 Euro/m<sup>3</sup> (i.e., about 4.9 Euro/GJ), both representing substantial additional costs (Faaij & Domac 2006). Other biomass streams such as wood pellets are currently exempted in the EU. A proposed detaxation Directive by the EC (in Europe, the reduction of taxes on biofuels is often referred to as detaxation), directs that member states will be allowed, but not mandated, to give fiscal resources to promote biofuels. However, this directive is very complex and equity concerns are reported since it may not be politically expedient to give tax advantages to imported product rather than developing domestic biofuel industries in individual EU countries (USDA/EU 2003; ESMAP 2005). Nevertheless and despite the lack of specific internationally agreed trade and tax schemes, many countries show a growing interest in international biomass trade since it can provide the biofuels' raw materials at prices lower than those of domestic supplies. Even Sweden, one of the biggest consumers of bioenergy in Europe with a substantial domestic production, imports large amounts of biomass to meet its demand (Hansson, Berndes & Börjesson 2006).

The importance of international trade aspects for bioenergy-related products is recognized by international organizations (e.g., EC, World Trade Organization). As a result, existing policies, fiscal frameworks, and (agricultural) schemes are currently reconsidered and biofuels are included in future lists of environmental goods and services for which tariff reductions are negotiated (IEA/OECD 2004), all with the intention to stimulate and open up international trade in these products.

#### Biofuel quality standards

A multitude of reasons can be identified that may explain the difficulties with international trade in biomass, biofuels, and the development of related schemes and agreements. A critical factor in enabling large-scale trade is the application of internationally accepted (technical) biofuel quality standards. Governmental bodies use fossil-fuel quality standards to help protect public health and the environment from harmful emissions from ICE vehicles, and to help ensure compatibility between fuels and vehicles. Such standards formed for instance the basis for the gradual phasing-out of lead from gasoline, and the reduction of sulphur content in petroleum fuels, as described in chapter 2. Moreover, fuel quality standards are an important component since they make global trade possible, and ensure approval of the biofuels by car manufacturers and the public (Steenberghen & López 2007). Unfortunately, international standards for biofuels are not yet abundantly developed.

Theoretically, by implementing a standard for minimum fuel content of non-petroleum (e.g., renewable) fuel, governments could similarly use regulation to drive the market (EIA/OECD 2004). This approach has the advantage of clearly defining the market share for specific types of fuels (e.g.,

biodiesel, ethanol), and creates a stable environment to promote fuel production, demand, and market development. However, a disadvantage of this approach is that costs are uncapped, i.e., fuel providers must comply regardless of costs. The next sub-section discusses important prerequisites for the set up of standards, and why this is a complex process regarding to bioenergy.

#### Biomass sustainability criteria and certification

The renewable energy industry is one of Europe's fastest growing sectors (Domac, Richards & Risovic 2005). In this sector, bioenergy is currently the most important source of renewable energy in the Netherlands (TaskForce 2006). Although great expectations exist about the application of bioenergy and biofuels, large-scale utilization comes together with potential high risks that cannot be ignored. One might think about environmental and ecological issues (e.g., potential loss of biodiversity, soil erosion, freshwater use, nutrient leaching, pollution from fertilizers), and adverse economical and social effects (e.g., quality of employment, use of child labor, health effects) (Faaij & Domac 2006). In order to address these potential concerning issues, large-scale international trade in this sector must rely on sustainable (in the broadest sense) production of biomass for energy. This requires the development of criteria, project guidelines and a certification system, supported by international bodies (IEA/T40 2006). Certification of biomass is an important means to prevent the discussed negative environmental and social side-effects. By setting up minimum social and ecological standards, and tracing/inspecting biomass from production to end-use, the sustainability of biomass can then be ensured.

From this perspective and on behalf of the central Dutch government, project group 'Duurzame productie van biomassa' recently formulated a set of generic principles, criteria and indicators which form a framework for sustainable production and processing of biomass to energy (for both electricity production and transportation fuels). The framework is based on six relevant sustainability themes according to the 'Triple P's' (i.e., People, Planet, Profit). Within the framework, principles are defined as basis for quality demands and are formulated as clear objectives with no room for discussion or other interpretations. The criteria are specific translations of the principles into unambiguous demands to be satisfied. Indicators are the quantitative or qualitative parameters that make criteria testable in practice (TaskForce 2007). Table 12 summarizes the six sustainability themes and derived principles for biomass to energy in a sustainable way. Both form the points of departure for the framework with criteria and indicators which are presented in appendix F (in Dutch).

**Table 12: Themes and principles for sustainable production of biomass for energy, freely translated from TaskForce (2007: p.7 & p.10)**

Sustainability theme	Principle
GHGs	The GHG balance of the production chain and the application of biomass is positive
Competition with food or other local applications	Biomass production is not to the detriment of important carbon reservoirs in the vegetation and in the ground
Biodiversity	Biomass production for energy shall not jeopardize food supply and local applications (e.g., energy supply, medicines, construction materials)
Environment	Biomass production is not to the detriment of protected or vulnerable biodiversity, and where possible fortifies biodiversity
Prosperity	
Well-being	During biomass production and processing, soil and ground quality are maintained or improved
	During biomass production and processing, surface- and groundwater are not exhausted, and water quality is maintained or improved
	During biomass production and processing, open air quality is maintained or improved
	Biomass production shall contribute to local prosperity
	Biomass production shall contribute to the employees well-being and local population

In order to shape impetus, the framework is developed in cooperation with Dutch industry partners, NGOs, societal groups, financial organizations and scientists, with the intention to match as closely as possible with international initiatives and regulation. Additionally, no distinction is made between imported and domestically produced biomass. Consequently, the framework may serve as guideline in an international context. Though, the initial and primary rationale of the framework is to provide advice during policy development for the application of biomass in the Dutch energy supply system. This is planned for the upcoming years and may include substantial adaptation of the framework. An important finding by the project group is that not yet all criteria can be assigned to measurable and practically usable indicators for various persistent reasons. This critical issue receives therefore further (international) investigation. Obviously, a national framework is not sufficient. In the end, a reliable, thorough, comprehensive, and internationally agreed framework is indispensable to create the required quality standards as discussed before. Consequently, this framework may ultimately enable and stimulate large-scale global trade (and thus utilization) in biomass, bioenergy and biofuels arisen in a social responsible manner. However, the framework must not become a barrier in itself to a global biomass-based economy, unambiguously a challenging task.

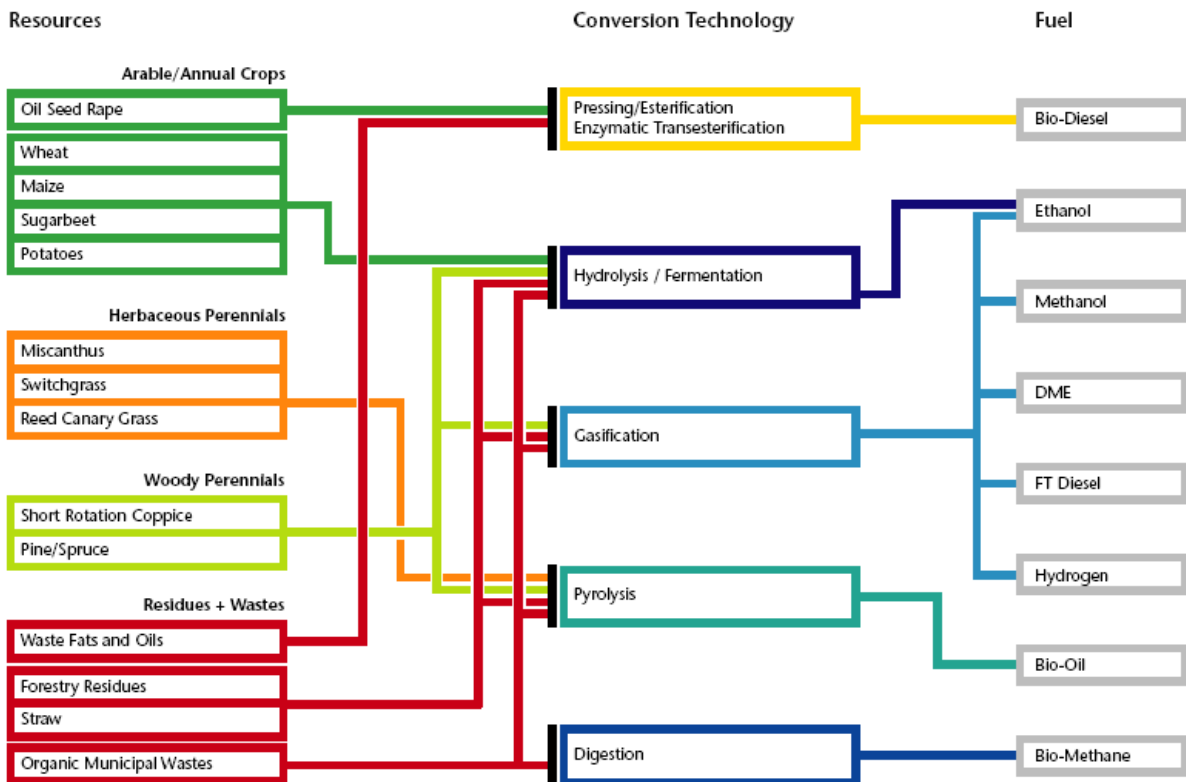
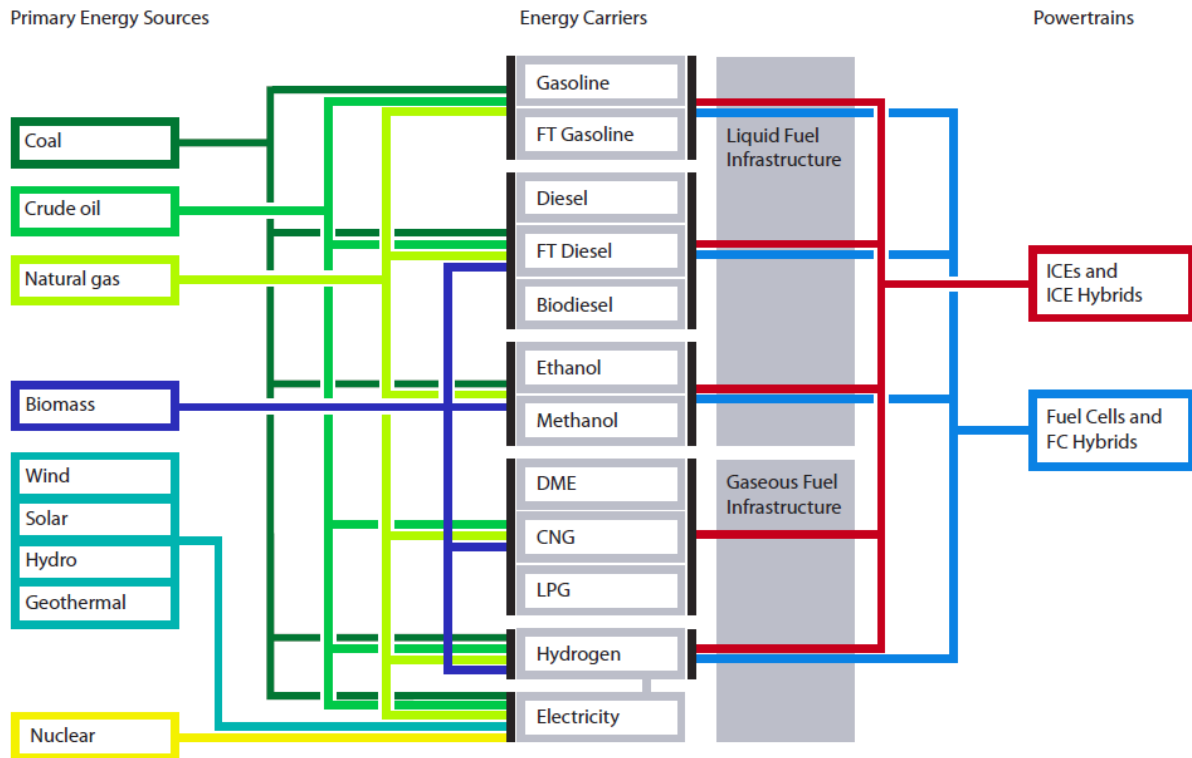
## 7.5 Closing remarks

Biofuels for road transportation purposes as ethanol and biodiesel have had a long history, and may flourish well at large-scale in the future. From 1900 onwards, biofuel production has had many peaks and valleys. Each time production rose or fell, it responded to complex combinations of changes in demand, economical and political interests. Despite the fact that influential men such as Henry Ford and Rudolph Diesel saw the future of renewable fuels, a political and economic struggle in the early 20<sup>th</sup> century restricted global-scale industry breakthrough for the forthcoming decades.

More recently however, biofuels experiencing again unprecedented levels of attention due to its value as alternative to dominant petroleum fuels, and its mitigating potential for concerning global issues like climate change, oil price fluctuations, and dependency on political instable regions. Besides the traditional bioenergy crop, innovative feedstock and process technologies are being developed which are expected to gain even more socio-economic and environmental benefits. Although these second-generation biofuels are only just found in immature and non-commercial laboratory settings, their potential makes them increasingly desirable for the mid-long term.

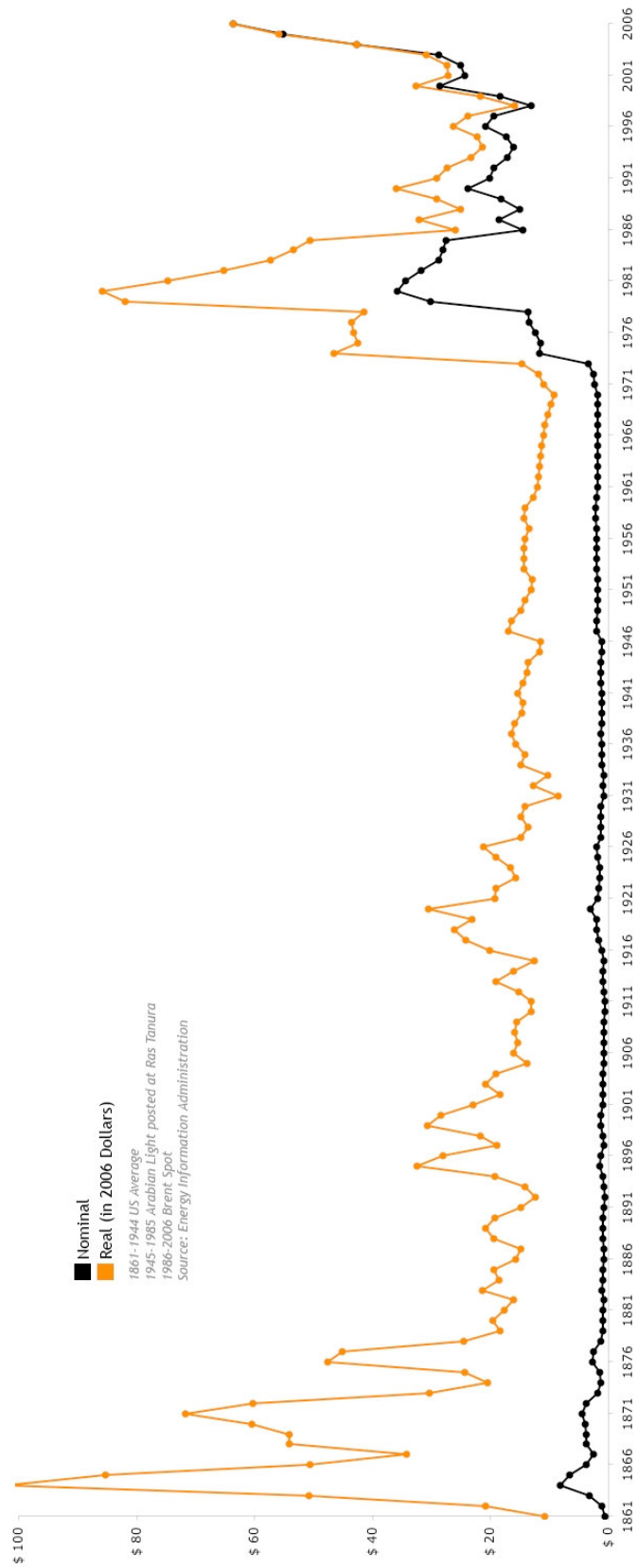
A shift towards a bioenergy-based economy requires tremendous societal change efforts. Considering the Brazilian experience, heavy governmental intervention and economic support seem initial key prerequisites. However, policy solutions and agreement in an international context are fundamentally important for global-scale commercialization of biofuels. Additionally, alignment and harmonization should be achieved with relevant stakeholders (e.g., oil suppliers, car manufacturers, end-consumers), and current practices and possibilities. Only then biofuels' critical issues like price, sustainability certification, and international trade may be addressed sufficiently, a challenging but valuable task.

## Appendix B: Possible pathways of advanced transport (bio)fuels



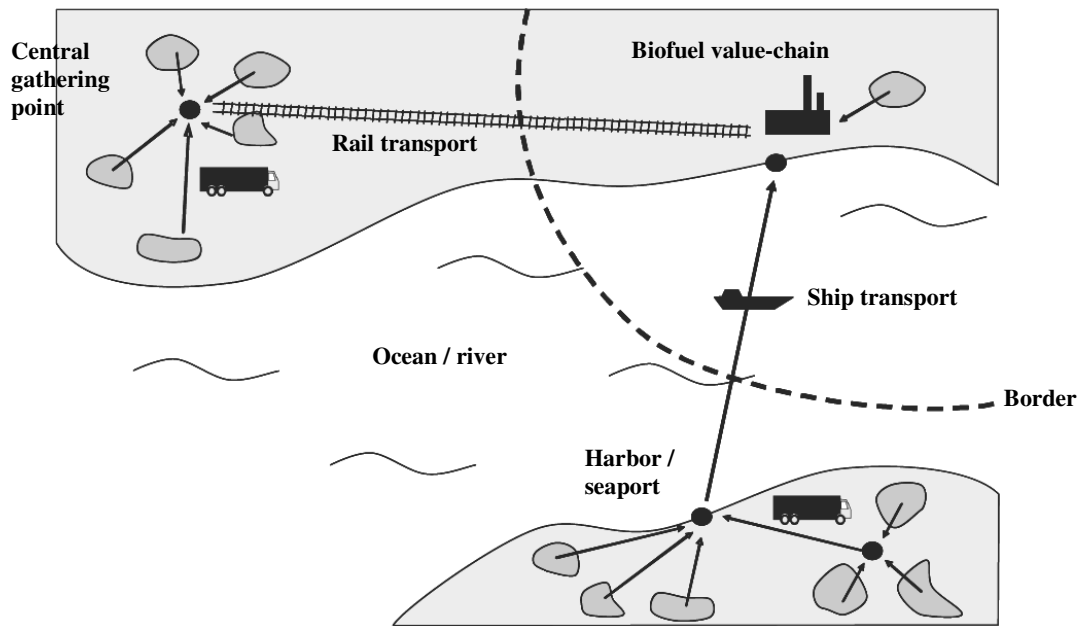
Source: WBCSD (2004: p.67 & 110).

## Appendix C: Long-term oil price trend



Via: <http://www.olino.org/articles/2006/08/05/stijgende-olieprijs>.

**Appendix D: Front-end modalities in the biofuel supply chain (schematic)**



Source: Edited from IEA/T40 (2006: p.5).



## Appendix E: Ethanol's (potential) production and plans for use per region

Summary of ethanol production (other than Brazil and USA) and plans for ethanol use

Country	Production (2001)	Remarks
Australia	150 Ml/yr (current production – all uses; fuel uses).	Plan for 2-5 % blend nationwide by 2010, corresponding to 1–2 Gl/yr production.
Canada	240 Ml/yr (current production – all uses). Capacity 600 Ml/yr.	Ethanol potential 1.35 Gl/yr by 2010, which corresponds to 35 % market penetration.
Central America	Most countries are planning fuel ethanol. Capacity 200 Ml/yr.	The main aim is to produce ethanol for the US market, rather than for domestic consumption.
China	3 Gl/yr (current production – all uses; just 1 Gl/yr as fuel).	Plans to produce additional 3 Gl/yr from maize, sweet sorghum, cassava and sugar cane.
Colombia	Potential market 0.9 Gl/yr from 2005.	Ethanol blend will be compulsory in cities with over 500,000 population.
Peru	Plans to produce 150 Ml/yr.	This programme aims primarily at the export market, mainly the USA.
India	1.0 Gl/yr (current production – all uses). Capacity 3.2 Gl/yr.	Plans for 5 % blend; trial at 300 refuelling stations; initial demand 350 Ml/yr.
Malawi	About 20 Ml/yr.	One of the oldest programmes in Africa. Malawi has been blending 15 % since 1982.
South Africa	385 Ml/yr from coal and gas and 40 Ml/yr from cane.	Plans for 12 % blend nationwide; there are plans to increase fermentation of ethanol from cane.
Thailand	150 Ml/yr (current production – all uses).	Plan for 10 % blend, using molasses, cassava, and sugar cane, corresponding to 700 Ml/yr
Others: Cuba, Ethiopia, Taiwan, Zambia, etc.	Production ranging from a few Ml to hundreds of Ml.	Mostly ethanol from sugar cane to be blended with petrol in various proportions. Some ethanol-diesel blends. Programmes are at various stages, either for domestic use or exports.

Ethanol potential production from different feedstocks (Gt)

Country/region and feedstock	2010	2020	2030	2050
Brazil – ethanol from sugar cane	21.0	61.3	121.2	309.6
Rest of Latin America – ethanol from sugar cane	4.4	24.2	42.7	59.8
India – ethanol from sugar cane	5.9	23.6	49.7	100.6
Africa – ethanol from sugar cane	1.6	16.6	35.6	65.9
Asia, except China – from sugar cane	5.6	19.8	31.2	54.4
China – ethanol from sugar cane	1.9	7.6	16.0	38.6
Middle East– ethanol from sugar cane	0.3	1.2	2.0	3.7
World – ethanol from sugar cane	40.7	154.3	298.4	632.6
EU – ethanol from grain + beet	12.1	27.3	27.3	27.3
North America – ethanol from grain	28.9	68.2	68.2	68.2
Rest of the world – ethanol from grain	4.6	10.6	10.6	10.6
Ligno-cellulosic ethanol	0.0	21.2	203.0	1,036.4
Total from all feedstocks	86.3	281.7	607.6	1,775.1
Share of ethanol in estimated petrol demand	5 %	13 %	25 %	54 %

Source: Rosillo-Calle & Walter (2006: p.24 & 25).

## Appendix F: Biomass certification: criteria and indicators

<b>Principe 1: De broeikasgasbalans van de productieketen en toepassing van de biomassa is positief</b>	
<p><b>Criterium 1.1:</b> Bij de toepassing van biomassa dient er over de gehele keten een netto emissiereductie van broeikasgassen op te treden. De reductie wordt berekend ten opzichte van een referentiesituatie met fossiele brandstoffen.</p>	<p><b>Indicator 1.1.1 (minimumeis)</b> De emissiereductie van broeikasgassen bedraagt minstens 50-70%<sup>2</sup> voor elektriciteitsproductie en ten minste 30% voor biobrandstoffen, berekend met de methodiek beschreven in hoofdstuk 4. Dit zijn minimumeisen. Daarbij dient het uitgangspunt te zijn dat beleidsinstrumenten een hoger percentage bevorderen boven de minimumeis door sterk te differentiëren naar de emissiereductie van broeikasgassen.</p>
<b>Principe 2: Biomassaproductie gaat niet ten koste van belangrijke koolstofreservoirs in de vegetatie en in de bodem.</b>	
<p><b>Criterium 2.1:</b> Behoud van bovengrondse (vegetatie) koolstofreservoirs bij aanleg van biomassa-eenheden.</p>	<p><b>Indicator 2.1.1 (minimumeis)</b> De aanleg van nieuwe biomassa productie-eenheden vindt niet plaats in gebieden waarbij het verlies aan bovengrondse koolstof opslag niet terugverdiend kan worden in een periode van tien jaar biomassaproductie. De referentiedatum is 1 januari 2007, met uitzondering van die biomassastromen waarvoor al een referentiedatum geldt uit andere (in ontwikkeling zijnde) certificeringssystemen.</p>
<p><b>Criterium 2.2:</b> Behoud van ondergrondse (bodem) koolstofreservoirs bij aanleg van biomassa-eenheden.</p>	<p><b>Indicator 2.2.1 (minimumeis)</b> De aanleg van nieuwe biomassa productie-eenheden vindt niet plaats in gebieden met een groot risico van aanzienlijke koolstofverliezen uit de ondergrond, zoals bepaalde graslanden, veengebieden, mangroves en natte gebieden. De referentiedatum is 1 januari 2007, met uitzondering van die biomassastromen waarvoor al een referentiedatum geldt uit andere (in ontwikkeling zijnde) certificeringssystemen.</p>
<b>Principe 3: Biomassaproductie voor energie mag de voedselvoorziening en lokale biomassa-toepassingen (energievoorziening, medicijnen, bouwmaterialen) niet in gevaar brengen.</b>	
<p><b>Criterium 3.1</b> Inzicht in verandering van landgebruik in de regio van de biomassa productie eenheid</p>	<p><b>Rapportage 3.1.1 (alleen als Nederlandse overheid hierom vraagt)</b> Informatie over veranderd landgebruik in de regio, inclusief toekomstige ontwikkelingen (als informatie beschikbaar is)</p>
<p><b>Criterium 3.2</b> Inzicht in verandering van prijzen van voedsel en grond in de regio van de biomassa productie eenheid</p>	<p><b>Rapportage 3.2.1 (alleen als Nederlandse overheid hierom vraagt)</b> Informatie over veranderingen in prijzen van grond en voedsel in de regio, inclusief toekomstige ontwikkelingen (als informatie beschikbaar is)</p>
<b>Principe 4: Biomassaproductie gaat niet ten koste van beschermde of kwetsbare biodiversiteit en versterkt waar mogelijk de biodiversiteit.</b>	
<p><b>Criterium 4.1:</b> Geen overtreding van nationale regels en wetten die op biomassaproductie en het productiegebied van toepassing zijn.</p>	<p><b>Indicator 4.1.1 (minimumeis)</b> Er wordt voldaan aan relevante nationale en lokale regels, wat betreft:</p> <ul style="list-style-type: none"> <li>• Landeigendom- en landgebruikrechten;</li> <li>• Bos- en plantagebeheer en -exploitatie;</li> <li>• Beschermde gebieden;</li> <li>• Wildbeheer;</li> <li>• Jacht;</li> <li>• Ruimtelijke ordening</li> <li>• Nationale regels voortkomend uit ondertekening van internationale conventies CBD (Convention on Biological Diversity) en CITES (Convention on International Trade in Endangered Species).</li> </ul>
<p><b>Criterium 4.2:</b> Bij nieuwe of recente aanleg, geen aantasting van biodiversiteit door biomassaproductie in beschermde gebieden.</p>	<p><b>Indicator 4.2.1 (minimumeis)</b> Biomassaproductie vindt niet plaats in recent ontgonnen gebieden die door de overheid zijn aangemerkt als 'gazetted protected areas', of in een zone van 5 km rond deze gebieden. De referentiedatum is 1 januari 2007, met uitzondering van die biomassastromen waarvoor al een referentiedatum geldt uit andere (in ontwikkeling zijnde) certificeringssystemen.</p> <p>Indien biomassaproductie wel plaats vindt in bovengenoemde gebieden, dan alleen als dit onderdeel is van het beheer om de biodiversiteitswaarden te beschermen.</p>

<p><b>Criterium 4.3:</b> Bij nieuwe of recente aanleg, geen aantasting van biodiversiteit in overige gebieden met hoge biodiversiteitswaarde, kwetsbaarheid of hoge agrarische natuur- en/of cultuurwaarden.</p>	<p><b>Indicator 4.3.1 (minimumeis)</b> Biomassaproductie vindt niet plaats in recent ontgonnen gebieden die door betrokken partijen zijn geclassificeerd als 'High Conservation Value' (HCV) gebieden, of in een zone van 5 km rond deze gebieden. De referentiedatum is 1 januari 2007, met uitzondering van die biomassastromen waarvoor al een referentiedatum geldt uit andere (in ontwikkeling zijnde) certificeringssystemen. De volgende gebieden worden beschouwd als HCV gebieden:</p> <ul style="list-style-type: none"> <li>• Gebieden met bedreigde of beschermde soorten of ecosystemen, op basis van de criteria van HCV categorieën 1, 2 en 3;</li> <li>• Gebieden met hoge kwetsbaarheid (bijv. hellingen en natte gebieden), op basis van de criteria van HCV categorie 4;</li> <li>• Gebieden met hoge natuur- en cultuurwaarden, op basis van de criteria van HCV categorieën 5 en 6 en criteria voor 'high nature value farmlands'.</li> </ul> <p>Door middel van een dialoog met lokale betrokkenen dient vastgesteld te worden waar de HCV-gebieden zich bevinden.</p> <p>Als biomassaproductie wel plaats vindt in bovengenoemde gebieden, dan alleen als dit onderdeel is van het beheer om de biodiversiteitswaarden te beschermen.</p>
<p><b>Criterium 4.4:</b> Bij nieuwe of recente aanleg, behoud of herstel van biodiversiteit binnen biomassaproductie-eenheden.</p>	<p><b>Indicator 4.4.1 (minimumeis)</b> Als biomassaproductie in recent ontgonnen gebieden (ná 1 januari 2007) plaatsvindt, wordt ruimte gegeven aan set-aside gebieden (minimaal 10%).</p> <p><b>Rapportage 4.4.2</b> Als biomassaproductie in recent ontgonnen gebieden (ná 1 januari 2007) plaatsvindt, moet worden aangegeven:</p> <ul style="list-style-type: none"> <li>- In welke landgebruikzones de biomassaproductie eenheid zich bevindt;</li> <li>- Hoe versnippering wordt tegengegaan;</li> <li>- Of ecologische corridors worden toegepast;</li> <li>- Of het hier gaat om herstel van gedegradeerde gebieden.</li> </ul>
<p><b>Criterium 4.5:</b> Versterking van biodiversiteit waar dat mogelijk is, bij aanleg en door beheer van bestaande productie eenheden.</p>	<p><b>Rapportage 4.5.1</b> Good practices worden toegepast op en rond de biomassa productie-eenheid ter versterking van de biodiversiteit, om rekening te houden met ecologische corridors en versnippering zo veel mogelijk tegen te gaan.</p>

**Principe 5: Bij de productie en verwerking van biomassa blijven de bodem en de bodemkwaliteit behouden of worden ze verbeterd.**

<p><b>Criterium 5.1:</b> Geen overtreding van nationale regels en wetten die op bodembeheer van toepassing zijn.</p>	<p><b>Indicator 5.1.1 (minimumeis)</b> Er wordt voldaan aan relevante nationale en lokale regels en wetten, wat betreft:</p> <ul style="list-style-type: none"> <li>• Afvalbeheer;</li> <li>• Gebruik van agrochemicaliën (kunstmest en pesticiden);</li> <li>• Mineralenhuishouding;</li> <li>• Voorkomen bodemerrosie;</li> <li>• Milieueffect rapportage;</li> <li>• Bedrijfsaudits.</li> </ul> <p>Minimaal moet worden voldaan aan de Stockholm conventie (12 schadelijkste pesticiden), ook waar nationale wetgeving ontbreekt.</p>
<p><b>Criterium 5.2:</b> Bij de productie en verwerking van biomassa worden best practices toegepast om de bodem en bodemkwaliteit te behouden of te verbeteren.</p>	<p><b>Rapportage 5.2.1</b> Formulering en toepassing van een strategie gericht op duurzaam bodembeheer voor het:</p> <ul style="list-style-type: none"> <li>• Voorkomen en bestrijden van erosie;</li> <li>• Behoud van voedingsstoffenbalans;</li> <li>• Behoud van organisch stof in de bodem;</li> <li>• Voorkomen van bodemverzilting.</li> </ul>
<p><b>Criterium 5.3:</b> Het gebruik van restproducten is niet in strijd met andere lokale functies voor het behoud van de bodem.</p>	<p><b>Rapportage 5.3.1</b> Gebruik van agrarische restproducten gaat niet ten koste van andere essentiële functies voor het behoud van de bodem en de bodemkwaliteit (zoals organisch stof, 'mulch', stro voor behuizing).</p> <p>Restproducten van het biomassaproductie- en verwerkingsproces worden optimaal gebruikt (dus bijvoorbeeld niet onnodig branden of afvoeren).</p>

**Principe 6: Bij de productie en verwerking van biomassa worden grond- en oppervlaktewater niet uitgeput en wordt de waterkwaliteit gehandhaafd of verbeterd.**

<p><b>Criterium 6.1:</b> Geen overtreding van nationale regels en wetten die op waterbeheer van toepassing zijn.</p>	<p><b>Indicator 6.1.1 (minimumeis)</b> Er wordt voldaan aan relevante nationale en lokale regels en wetten, wat betreft:</p> <ul style="list-style-type: none"> <li>• Gebruik van water voor irrigatie;</li> <li>• Gebruik van bodemwater;</li> <li>• Gebruik van water voor agrarische doelen in stroomgebieden;</li> <li>• Waterzuivering;</li> <li>• Milieueffectrapportages;</li> <li>• Bedrijfsaudits.</li> </ul>
--	--

<b>Criterion 6.2:</b> Bij de productie en verwerking van biomassa worden best practices toegepast om watergebruik te beperken en grond- en oppervlaktewaterkwaliteit te behouden of verbeteren.	<b>Rapportage 6.2.1</b> Formulering en toepassing van een strategie gericht op duurzaam waterbeheer met betrekking tot: <ul style="list-style-type: none"> <li>• Efficiënt watergebruik;</li> <li>• Verantwoord gebruik van agrochemicaliën.</li> </ul>
<b>Criterion 6.3:</b> Bij de productie en verwerking van biomassa wordt geen gebruik gemaakt van water uit niet-hernieuwbare bronnen.	<b>Indicator 6.3.1 (minimumeis)</b> Irrigatie of water voor de verwerkingindustrie is niet afkomstig van niet hernieuwbare bronnen.

**Principe 7: Bij de productie en verwerking van biomassa wordt de luchtkwaliteit gehandhaafd of verbeterd.**

<b>Criterion 7.1:</b> Geen overtreding van nationale regels en wetten die op emissies en luchtkwaliteit van toepassing zijn.	<b>Indicator 7.1.1 (minimumeis)</b> Er wordt voldaan aan relevante nationale en lokale regels en wetten wat betreft: <ul style="list-style-type: none"> <li>• Luchtemissies;</li> <li>• Afvalbeheer;</li> <li>• Milieueffectrapportages;</li> <li>• Bedrijfsaudits.</li> </ul>
<b>Criterion 7.2:</b> Bij de productie en verwerking van biomassa worden best practices toegepast om emissies en luchtvervuiling te beperken.	<b>Rapportage 7.2.1</b> Formulering en toepassing van een strategie gericht op minimale luchtemissies, met betrekking tot: <ul style="list-style-type: none"> <li>• Productie en verwerking;</li> <li>• Afvalbeheer.</li> </ul>
<b>Criterion 7.3:</b> Geen branden als onderdeel van aanleggen of beheer van biomassa productie-eenheden.	<b>Indicator 7.3.1 (minimumeis)</b> Branden wordt niet toegepast bij de aanleg of het beheer van biomassaproductie-eenheden, tenzij in specifieke situaties zoals beschreven in ASEAN richtlijnen of andere regionale good practices.

**Principe 8: Productie van biomassa draagt bij aan de lokale welvaart**

<b>Criterion 8.1:</b> Positieve bijdrage van eigen bedrijfsactiviteiten aan de lokale economie en bedrijvigheid.	<b>Rapportage 8.1.1</b> Beschrijving van: <ul style="list-style-type: none"> <li>• De directe economische waarde die wordt gecreëerd;</li> <li>• Beleid, praktijk en besteed budget aan lokale toeleveranciers;</li> <li>• De procedures voor aanstelling van lokaal personeel en het aandeel van lokaal senior management.</li> </ul> Gebaseerd op de Economic Performance Indicators EC 1, 6 & 7 van GRI (Global Reporting Initiative).
---	--

**Principe 9: Productie van biomassa draagt bij aan het welzijn van de werknemers en de lokale bevolking**

<b>Criterion 9.1</b> Geen negatieve effecten op arbeidsomstandigheden van werknemers	<b>Indicator 9.1.1 (minimumeis)</b> Voldoen aan de Tripartite Declaration of Principles concerning Multinational Enterprises and Social Policy (opgesteld door de International Labour Organisation).
<b>Criterion 9.2</b> Geen negatieve effecten op mensenrechten	<b>Indicator 9.2.1 (minimumeis)</b> Voldoen aan de Universele Verklaring van de Rechten van de Mens van de Verenigde Naties. Hierbij gaat het om: non-discriminatie; vrijheid van vakvereniging, kinderarbeid; gedwongen en verplichte arbeid; disciplinaire praktijken, veiligheidspraktijken en rechten van inheemse volkeren.
<b>Criterion 9.3</b> Het gebruik van land leidt niet tot schending van officieel eigendom en gebruik, en gewoonterecht zonder vrije en voorafgaande instemming van voldoende geïnformeerde lokale bevolking	<b>Indicator 9.3.1 (minimumeis)</b> Voldoen aan de volgende eisen: <ul style="list-style-type: none"> <li>• Geen landgebruik zonder instemming van voldoende geïnformeerde oorspronkelijke gebruikers;</li> <li>• Landgebruik is nauwkeurig omschreven en officieel vastgelegd;</li> <li>• Officieel eigendom en gebruik, en gewoonterecht van inheemse bevolking worden erkend en gerespecteerd.</li> </ul>
<b>Criterion 9.4</b> Positieve bijdrage aan het welzijn van lokale bevolking	<b>Rapportage 9.4.1</b> <ul style="list-style-type: none"> <li>• Beschrijving van programma's en praktijken om de effecten van bedrijfsactiviteiten op lokale bevolking te bepalen en beheren;</li> </ul> Gebaseerd op de Social Performance Indicator SO1 van het GRI (Global Reporting Initiative).
<b>Criterion 9.5</b> Inzicht in mogelijke schendingen van de integriteit van het bedrijf	<b>Rapportage 9.5.1</b> Beschrijving van: <ul style="list-style-type: none"> <li>• Mate van training en risico analyse om corruptie te voorkomen;</li> <li>• Ondernomen acties in antwoord op gevallen van corruptie.</li> </ul> Gebaseerd op de Social Performance Indicator SO2, SO3 en SO4 van het GRI (Global Reporting Initiative).

Source: TaskForce (2007: p. 11-19).