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Mitigation

An integrated framework to assess spatial and related implications of biomass delivery chains

E. Annevelink
B. Elbersen
H.W. Elbersen
J.P.M. Sanders

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Authors

E. Annevelink
B. Elbersen
H.W. Elbersen
J.P.M. Sanders

With contributions of members of the project team ME4:
Wageningen UR - Valorisation Plant Production systems - F. van der Hilst & J.P.M. Sanders
Wageningen UR - Food & Biobased Research - E. Annevelink, H.W. Elbersen,
J.W.A. Langeveld, M.J.A. van den Oever & R. Poppens
Wageningen UR - Alterra - B.S. Elbersen, I.R. Geijzendorffer, J. Roos-KleinLankhorst,
P.J. Kuikman, J.P. Lesschen, R.A. Smidt & I.G. Staritsky
UU - Copernicus Instituut - S. Breukers, J.M.C. van Dam, V. Dornburg, A.P.C. Faaij & M.P. de Wit
ECN - M. Londo, P. Lako & H. Mozaffarian
KEMA - R. Kalf
VU - University of Amsterdam - Institute for Environmental Studies - E. Bergsma, E. Cuppen & M. Hisschemöller

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Introduction

The overall objective of the ME4 research project was to develop an integrated framework to assess and analyse the spatial implications and related opportunities and consequences of an increased implementation of biomass delivery chains for energy, biofuels and biochemicals at different geographical levels. The research project has addressed four main topics described below.

Biomass in The Netherlands and EU present and future situation

In this study two contrasting scenarios for the integrated analysis of biomass delivery chains were selected, and combined with three levels of low, base, and high policy intervention. Results indicate that the total available land for bioenergy crop production could amount to 900,000 km^2 by 2030. Agricultural policy and technological development are key to open up the potential.

Framework tool for integrated spatial design and assessment of regional biomass chains

A framework tool for the integrated spatial design and assessment of regional biomass delivery chains was designed and built. The framework tool can be used to support the assessment of the practical implementation of biomass delivery chains. The tool can be supportive in the required communication process, especially through provision of quick and better understanding of the spatial, environmental and economic consequences of a large range of choices that need to be made to come to a final chain designing and practical implementation in a region.

Regional biomass chains evaluation

Five cases were studied. The regional prospects and consequences of bioenergy production were assessed for different biomass production chains the northern and eastern part of the country. A GIS-BIOLOCO tool was developed that supports the sustainability assessment of biomass delivery chains at a regional level, in terms of the regional availability of biomass resources, costs, logistics and spatial implications. Also 1st generation (sugar beet) and 2nd generation (Miscanthus) bioethanol chains were compared.

Dialogue on sustainability of bioenergy

The Biomass Dialogue has offered an understanding of the divide with respect to sustainability of biomass to energy as well as a possible way-out. A step-by-step approach as proposed in the recommendations may reconcile the divergent perspectives, focusing on learning by doing through small-scale projects so that risks can be signalled at an early stage.

Short summary in Dutch

Introductie

Het hoofddoel van het project was een geïntegreerde raamwerkmethode te maken. Daarmee kunnen de ruimtelijke gevolgen, en gerelateerde kansen en consequenties worden beoordeeld en geanalyseerd, van een verhoogde implementatie van biomassaketens voor energie, transportbrandstoffen en chemicaliën op verschillende geografische niveaus. Het project heeft de vier onderstaande hoofdonderwerpen behandeld.

Biomassa in Nederland en de EU: huidige en toekomstige situatie

In deze studie zijn twee contrasterende scenario's gekozen voor de geïntegreerde analyse van biomassaketens, die gecombineerd zijn met drie niveaus van politieke sturing: laag, basis en hoog. Een conclusie is dat in 2030 potentieel 900,000 km^2 land in Europa vrijgemaakt kan worden voor de productie van energiegewassen. Landbouwpolitiek en technologische ontwikkelingen zijn cruciaal om dit potentieel te ontsluiten.

Raamwerkmethode voor geïntegreerd ruimtelijk ontwerp en beoordeling van regionale biomassaketens

Een raamwerkmethode voor het geïntegreerd ruimtelijk ontwerp en beoordeling van regionale biomassaketens is ontworpen en gebouwd. Het is de bedoeling dat de raamwerkmethode helpt de praktische haalbaarheid van de invoering van biomassaketens te beoordelen. Het raamwerk ondersteunt het benodigde communicatieproces, vooral door het snel en beter begrijpen van de ruimtelijke-, milieu- en economische gevolgen van een grote hoeveelheid keuzes die gemaakt moeten worden om te komen tot het uiteindelijke ontwerp en implementatie van een biomassaketen in een regio.

Evaluatie van regionale biomassaketens

Er zijn vijf cases bestudeerd. Daarin zijn de regionale vooruitzichten en gevolgen van bioenergieproductie beoordeeld voor verschillende biomassaproductieketens in het noorden en het oosten van het land. Een GIS-BIOLOCO methode is ontworpen die ondersteuning biedt bij het beoordelen op duurzaamheid van biomassaketens op regionaal niveau, met name de regionale beschikbaarheid van biomassabronnen, kosten, logistiek en ruimtelijke effecten. Ook zijn 1^e (suikerbiet) en 2^e (Miscanthus) generatie bioethanol productieketens vergeleken.

Dialoog over duurzaamheid van bioenergie

De Biomassa Dialoog heeft inzicht geleverd over tegengestelde inzichten met betrekking tot duurzaamheid van bioenergie, maar ook over mogelijke oplossingen. Een stapsgewijze aanpak is voorgesteld, om divergerende perspectieven bij elkaar te brengen. Hierbij ligt de nadruk op 'leren-door-doen' in kleinschalige projecten, zodat risico's in een vroeg stadium gesignaleerd kunnen worden.

Extended summary

Introduction

The overall objective of the ME4 research project was to develop an integrated framework to assess and analyse the spatial implications and related opportunities and consequences of an increased implementation of biomass delivery chains for energy, biofuels and biochemicals at different geographical levels. Tapping into the national and regional biomass potential is quite difficult. The hypothesis of this project was that the biomass potential can be mobilized better if innovative regional biomass delivery chains are designed. Therefore, an integrated framework to assess spatial and related implications of sustainable regional biomass delivery chains is needed. The research project has addressed four main topics:

- design of sustainable regional biomass delivery chains and assessment of their spatial implications;
- develop an integrated framework to assess spatial and related implications;
- analyse and assess National & European possibilities for biomass production and utilisation under different scenarios;
- test methodology to actively involve stakeholders in the development of biomass chains.

Biomass in The Netherlands and EU present and future situation

Several aspects of the present and the future situation of biomass in The Netherlands and Europe have been studied. Key success factors were identified and evaluated that are crucial for successful bioenergy production chain development. These include:

- successful selection of a suitable location and, obtaining necessary licenses for operating bioenergy production technologies;
- organizing generic support for bioenergy initiatives at a wider scope;
- availability of sufficient reliable (information on) proven technology;
- sharing of independent (scientific) data on issues like odour, noise, and emissions from installations between stakeholders involved in the chain development.

In this study two contrasting scenarios for the integrated analysis of biomass delivery chains were selected, Global Economy (GE) and Regional Communities (RC), and combined with three levels of low, base, and high policy intervention. The objective was to outline extreme conditions, and to study what happens as a result of those conditions.

The Dutch biomass demand and supply in 2010-2030 was studied. The analysis tried to identify the main biomass sources under different scenario situations. The GE and RC Scenarios were used to further translate the 2020-2030 energy demand into a renewable energy and bioenergy demand. The assumed potentials for both the GE and RC scenarios are quite high, and can fulfil a considerable fraction of the biomass demand in each sector of the both scenarios. However, still additional biomass needs to be imported in order to match the demand for biomass in both scenarios.

The biomass resource potential and related costs in the EU-27 and the Ukraine have been determined in cooperation with the REFUEL project. Results indicate that the total available land for bioenergy crop production – following a 'food first' paradigm – could amount to 900,000 km^2 by 2030. First generation feedstock supply is available at production costs of 5–15 € GJ^{-1} compared to 1.5–4.5 € GJ^{-1} for second generation feedstocks.

Looking at the developments in European agriculture, it was studied how fast and to what maximum yield improvements can be realized in Europe in the coming decades and what the opportunities and relations are to biomass production. It is concluded that the potential to free-up agricultural lands for the production of bioenergy crops in Europe is considerable. Agricultural policy and technological development are key to open up the potential.

A key aspect in modelling the (future) competition between biofuels is the way in which production cost developments are computed. An analysis was executed with the European biofuel model BioTrans, which computes the least cost biofuel route.

The cumulative greenhouse gas emissions (GHG) of N_2O, net soil organic carbon fluxes and abated emissions from replacing fossil transport fuels by biofuels were evaluated for nine land use variants with MITERRA-Europe. It is found that it is possible to combine large-scale biomass production, sustain current food production levels without (in)direct land use changes and accomplish significant net environmental benefits in European agriculture.

Framework tool for integrated spatial design and assessment of regional biomass chains

A framework tool for the integrated spatial design and assessment of regional biomass delivery chains was designed and built. It contains four modules:

- pre-defined data;
- generation of national biomass potential maps;
- chain specification;
- impact assessments.

The framework tool can be used to support practical processes with stakeholders and researchers having the intention to practically implement biomass delivery chains. The development of the tool in this project has confirmed that a lot of practical knowledge, existing models, and data can be captured in a framework enabling an integrated view of both spatial consequences, environmental and economic performance of new biomass delivery chains designed in an iterative process with stakeholders and researchers.

The complexity of the biomass chains integrated in the present framework is still limited. Further application of the framework tool will increase the complexity of the biomass chains the framework can handle.

The development of the framework tool also confirmed that not all knowledge and data can be captured in a formalised framework environment. This especially applies to social criteria. This however, is not necessary as design and practical implementation of biomass delivery chains needs the involvement of many stakeholders in a wider communication process. The tool can be supportive in this interaction process, especially through provision of quick and better understanding of the spatial, environmental and economic consequences of a large range of choices that need to be made to come to a final chain designing and practical implementation in a region.

Regional biomass chains evaluation

The following five cases were studied: pellets, straw, 1st generation bioethanol from sugar beet, 2nd generation bioethanol from Miscanthus and biorefinery. The level of detail varies from case study to case study.

Perspectives and impacts of bioenergy production in The Netherlands has been assessed for a fictitious wood pellet production chain in the east of the country. Using the framework an assessment was made of GHG savings by combustion of the wood pellets. The framework tool covers the following NTA 8080 components: (parts of) environment, greenhouse gas balance, stakeholder consultations and prosperity. The remainder of NTA 8080 sustainability components are not covered, or only indirectly.

A GIS-BIOLOCO tool was developed that supports the sustainability assessment of biomass delivery chains at a regional level, in terms of the regional availability of biomass resources, costs, logistics and spatial implications. A straw-based bioenergy chain based on current land use in The Netherlands was assessed using the GIS-BIOLOCO application. Based on the straw supply map, GIS-BIOLOCO optimized the chain for the profit margin and generated a straw withdrawal pattern.

Two biofuel cases were compared: 1st generation bioethanol from sugar beet with 2nd generation bioethanol from Miscanthus. The main socio-economic impacts of the biofuel cases are:

- on very suitable soil cash crops are more profitable than bioenergy crops;
- on low suitable soil the production costs of biomass crops are very high;
- medium soils are the best locations for growing Miscanthus;
- feedstock production costs are higher for sugar beet than for Miscanthus and both are more costly than feedstock imported from abroad;
- domestically produced ethanol from biomass is not competitive with petrol prices (yet).

The main environmental impacts of the biofuel cases are:

- valuable methods have been found to assess the spatial variation of potential environmental impacts of bioenergy production spatially explicitly;
- the case study provides knowledge about preferable areas for bioenergy production and 'no-go' areas;
- there are trade-offs between the various environmental impacts: there are no areas where a shift towards bioenergy crop production results in only positive environmental impacts;
- conversion of arable land to Miscanthus generally gives positive environmental effects;
- conversion of pasture land to sugar beet generally gives severe negative environmental impacts.

The Biorefinery case is an example of much more complex biomass chains, since more than one product is manufactured from an agricultural crop or residue. So far the framework tool has not implemented these more complex chains yet.

Dialogue on sustainability of bioenergy

The Biomass Dialogue has offered an understanding of the divide with respect to sustainability of biomass to energy as well as a possible way-out. Part of the dialogue participants have stressed that we will have to accept that, in a learning by doing process, things may go wrong. The current Dutch 'culture' with respect to energy from biomass is featured by postponing action under the assumption that 'next generation' options will be really sustainable. If this remains the dominant attitude, we may never face a transition or we will be forced into it by global developments. For another part of dialogue participants, risk aversion is critical. The dialogue has highlighted a possible compromise between these two perspectives, as comes out of the recommendations. A step-by-step approach as proposed in the recommendations may reconcile the divergent perspectives, focusing on learning by doing through small-scale projects so that risks can be signalled at an early stage.

1. Introduction

1.1 Project organisation

This report gives an overview of the main results of the project 'An integrated framework to assess spatial and related implications of increased implementation of biomass delivery chains (ME4)'. The project was started in 2007 and final results were available in April 2011. It was commissioned within the National research programme 'Climate changes spatial planning' and co-funded by the European Union, the former Ministry of Agriculture, Nature and Food quality, Shell and the Province of Groningen. The partners in this project were Wageningen UR Food & Biobased Research (both the Valorisation of Plant Production chains chair & the Biobased Products group), Wageningen UR Alterra, Energy research Centre of the Netherlands (ECN), Copernicus Institute Utrecht University, KEMA and VU University Amsterdam.

1.2 Goal of the project

The overall objective of the research project was to develop an integrated framework to assess and analyse the spatial implications and related opportunities and consequences of an increased implementation of biomass delivery chains for energy, biofuels and biochemicals at different geographical levels.

This integrated framework will be used to assess the spatial, environmental (including ecological and landscape) and socio-economic performance of biomass delivery chains at different geographical levels. So on the one hand the integrated framework will help regional stakeholders to make well-funded choices and set up optimal regional biomass delivery chains containing all steps from biomass production to the delivery of products to the market. On the other hand, National stakeholders will also be able to use the framework to assess different bioenergy delivery chains and their potential, performance and (spatial) impacts under different scenarios, which include developments on national and supra-national level. Overall the framework should also help researchers to adapt and use existing models, knowledge and data for the integrated spatial assessment of biomass delivery chains and also to provide the opportunity to reuse components of the framework in different contexts.

1.3 Focus and scope of the project

Most key global outlooks and scenarios expect that biomass will be an important renewable source for bioenergy, biofuels and biochemicals in the next 50 years. The potential global supply of biomass for these purposes is very large. Though the biomass potential is large, the bulk of this potential still awaits active development. The actual volume of biomass supply depends and will vary with the timing in adoption of efficient agricultural management, rate of population growth, and other trends. Also, land use changes (LUC), land use management and sustainable integrated biomass production for non-food purposes need to be aligned with regional conditions to address the current food-feed-fuel discussion. Ecological and socio-economic conditions will vary from place to place and the selection and implementation of biomass production chains (both regional and world market) is therefore a regional issue.

However, at the regional level understanding about biomass potentials and biomass production and utilisation systems was still less well developed at the start of the project. This was particularly true when a variety of sustainability criteria (with ecological, economic and social dimensions) needs to be taken into account. Most studies focused on biomass potential but did not specify how to turn potentially available biomass into actually available biomass. Tapping into the national and regional potential is quite difficult. The hypothesis of this project was that the biomass potential can be mobilized better if innovative regional biomass delivery chains are designed. Therefore, an integrated framework to assess spatial and related implications of sustainable regional biomass delivery chains is needed.

1.4 Approach

The research project has addressed four main topics:

- design of sustainable regional biomass delivery chains and assessment of their spatial implications;
- develop an integrated framework to assess spatial and related implications;
- analyse and assess National & European possibilities for biomass production and utilisation under different scenarios;
- test methodology to actively involve stakeholders in the development of biomass chains.

The first topic was the actual design of sustainable regional biomass delivery chains, and the assessment of their spatial implications including their effects on land use, social and economic development and environment. The emphasis was put on a number of Dutch regional case studies. However, also European cases were studied in cooperation with the REFUEL project. ‘Biomass maps’ have been produced indicating the main land use changes that would take place when implementing these chains at the regional, national and European level.

Within the second topic an integrated framework and related analysis tools was developed that identifies and quantifies expected effects that result from competition for biomass or land, national and international developments and trends. This integrated framework can be used to facilitate realistic designing, planning and incorporation of biomass delivery chains at a regional level while providing information on opportunities and risks.

A strategic scenario analysis has addressed national and supra-national developments that affect the performance, potential and impacts of biomass production. Scenarios have served to determine the uncertainties, variability and potential choices that can be made when incorporating European and National agricultural policies, nature conservation, environmental standards, developments in the energy system and various markets for biomass conversion.

Key to successful implementation of biomass delivery chains is information and integration of land use functions. This has been achieved within the fourth topic through stakeholder involvement in a dialogue on sustainable biomass chains with stakeholders. This was a joint process of identification and implementation of (multi-functional) land use.

1.5 Structure of this report

Chapter 2 of this report deals with several aspects of the present and the future situation of biomass in The Netherlands and Europe. The key success factors influencing the efficiency of biomass production chain development policies in The Netherlands are an important issue. Two different scenarios are described that can be used for the integrated analysis of biomass delivery chains in The Netherlands. These scenarios are translated to Dutch biomass demand and supply in 2010-2030. On the European level the resource potential and costs are described. The influence of the European agricultural developments on bioenergy is another important aspect. Finally modelling technological learning and cost reductions over time is a topic in this chapter. In Chapter 3 the tools, models and approach are given for the integrated spatial design and assessment of regional biomass delivery chains. The topics that are covered are chain design, economic viability, biomass potentials and land use change effects. The assessment options deal with environmental impacts, economic and logistical impacts and social criteria. The chapter also gives a brief description of the integrated framework that was developed within the project. More information can be found in a separate manual document. Chapter 4 gives the results of various case studies of regional biomass chains. These results were generated with the framework and/or a selections of the available tools, models and approaches within the project. The following five cases were studied: pellets, straw, 1st generation bioethanol from sugar beet, 2nd generation bioethanol from Miscanthus and biorefinery. The level of detail varies from case study to case study. Chapter 5 describes the stakeholder dialogue in the context of the project that explored options for production and use of energy from biomass for The Netherlands. Finally Chapter 6 gives the main conclusions and recommendations.

2. Biomass in The Netherlands and EU: present and future situation

2.1 Introduction

In this Chapter we present the results of our assessments that shed more light on how to implement biomass to energy and biobased products and chemicals.

Biomass production, delivery and conversion chains have by their nature many interactions with the environment making implementation very complicated especially in a crowded country like The Netherlands. Lessons from past experiences can be drawn that may help policy makers and entrepreneurs implement future projects more efficiently. To see how the biomass for energy and biobased products and chemicals will develop under influence of different factors scenarios have been developed and used to show biomass supply and demand until 2030.

Developments in biomass application for The Netherlands are closely connected to the EU level. For example EU's renewable energy directive and biofuel directive are important drivers for the accelerating use of biomass resources in Europe and The Netherlands. Furthermore, bioenergy trade plays an important role in acquiring resources both within Europe, between member states, as internationally. In this light the production potential, costs and environmental impacts of dedicated bioenergy production in Europe were evaluated in four separate studies, summarized in sections 2.5-2.8.

2.2 Effectiveness of bioenergy production chain development policies in The Netherlands: key factors for success[1]

2.2.1 Introduction

Theoretical frameworks on bioenergy chain development suggest that five elements are crucial for successful bioenergy chain development: (i) availability of (proven) technology, (ii) access to information, (iii) access to feedstocks, financial means and markets, (iv) locations for new installations and (v) efficient lobby activities and public support.

In order to assess whether such conditions are fulfilled for bioenergy chain development in The Netherlands, we have interviewed nine bioenergy chains that were selected from a long list, using the following criteria:

- coverage of major bioenergy products (electricity, heat, biofuels, biogas);
- distribution over geographical regions;
- inclusion of small as well as larger initiatives;
- inclusion of successes and failures.

The selected initiatives include biogas (3), biofuels (2) and electricity/heat (4) (Table 1). Four additional interviews were held outside the initiatives to obtain background information on bioenergy production and utilization in The Netherlands: one firm selling bioenergy installations, one investment fund, one policy maker and one company processing animal manure. Chains size varies, most initiatives have running facilities, but two still are in the start-up phase. Representatives of the chains (mostly owners or managers) were asked questions on issues such as: (i) finding a location and obtaining permits, (ii) feedstock and technology used, (iii) chain organization, (iv) experiences with (local, provincial) government and (v) knowledge or information requirements.

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[1] Based on Langeveld et al.(2010) - Bioenergy production chain development in the Netherlands: key factors for success.

Table 1.
Background information on the interviews and production chains.

Code[1]	Chain type	Status production chain	People interviewed
G1	Medium to large digester	Running successfully	Research manager
G2	Small scale farm digester	Planned but not running, may be aborted	Initiator farmer
G3	Medium sized digester	Running after a smooth start-up	Owner farmer
C1	Medium scale combustion plant run by an electricity company	Running but had start-up problems	Research manager
C2	Large combustion plant run by an electricity company	Running but had start-up problems	Managers
C3	Medium size combustion installation linked to a greenhouse	Running, problems with housing of the installation	Owner warehouse
C4	Small farm combustion plant	Running after a smooth start-up	Farmer / managers
F1	Large methanol plant	Start-up, so far running smoothly	Plant manager
F2	Medium to large pure oil plant	Running, after construction problems	Owner
O1	Public investment fund	-	Expert
O2	Provincial authority	-	Policy makers
O3	Manure cleaning plant not producing any bioenergy	Running, no problems	Research manager
O4	Installer of fermentation and combustion installations	-	Director

[1] Fermentors are coded 'G', Combusting chains 'C', Fuel producers 'F', and other chain types 'O'.

2.2.2 Results

Problems reported by bioenergy chains relate to insufficient knowledge of (i) new technological concepts, and of (ii) (noise, emission, odour and other) nuisances caused during bioenergy production. Further, (iii) markets of feedstocks (wood, by-products, waste) and products (heat, CO_2) are underdeveloped; while (iv) some chains are experiencing extra problems finding a suitable location or obtaining necessary permits. Problems related to insufficient public support are most relevant for bioenergy chains depending on tax exemptions (pure vegetation oil transportation fuels) or requiring adaptation of legislation (location permits for farm fermenters). Not all problems are equally relevant. Some refer to practical problems that are also met while establishing conventional production chains: finding a market, selecting a reliable production technology, obtaining financial means or a suitable location and obtaining permits. While such problems are occurring in a wide range of sectors, they may be more relevant for emerging bioenergy chains (Table 2). This holds especially when technologies are still under development, feedstock or output markets are not fully mature and banks and authorities are still undecided on their attitude (supportive, discouraging) towards production routes.

Outcomes were, further, compared to problems reported in other countries: bioenergy production chains in Germany and France, the USA and Canada. Dutch cases appear to be of a rather small scale, especially those related to biofuels and biogas production, and mostly lack strong links with agro-industry. Barriers for biofuel abroad include economic factors (including lack of capital), limitations in know-how and institutional capacities, underdeveloped biomass and carbon markets. Problems in chain coordination and limited public support are largest problems for new bioenergy chains.

Recommendations to stimulate bioenergy production in the Netherlands refer to performance standards for new installation types, information on feedstock availability, protocols for heat exchange and on improved credit facilities.

Table 2.
General problems and specific problems for bioenergy production chain.

Issue	Non-bioenergy chains	Specific for bioenergy chains
1. Availability of technology	No specific problem	Insufficient access to proven technology for combustion of (waste or freshly harvested) wood, and for some forms of biofuel production
2. Access to knowledge and information	No specific problem	Insufficiently developed markets for bioenergy installation construction, for feedstock or heat sales
3. Access to feedstocks, credit and markets	No major problem (until recent outbreak of 'credit crisis')	Especially problematic for chains depending on 'new' feedstocks (waste or chipped wood, manure, co-products, waste) or supplying 'new' products (heat, CO_2)
4. Availability of a suitable location	General problem in The Netherlands (densely populated)	Has been especially problematic for digesters, as a general concept on the aspect of fermentation (agricultural or industrial) was lacking
5. Effective lobby / public support	Support for intensive livestock production is limited.	Tax exemptions needed for biofuels require political support. General opposition to concept of fuels made from food products (fuel vs. food)

2.2.3 Conclusion

While The Netherlands has defined clear objectives for increased domestic bioenergy production as specified in the Dutch National Renewable Energy Action Plan, in practice, new bioenergy production chains are meeting many problems. Realization of national bioenergy objectives requires improvements in the availability and dissemination of technology, development of biomass and bioenergy (heat) markets, credit availability and processes for obtaining planning permission. More generally, more policy and public support is needed.

2.3 Scenarios for the integrated analysis of biomass delivery chains[2]

Long-term scenarios (2030) can be used to analyse different pathways for the production of biomass in the EU and in regions of EU countries. More generally the question is how 'biobased economy chains' - including production of biomass for bioenergy, biochemicals and materials - may evolve, next to existing biomass chains for food and feed production. Such long-term scenarios differ with respect to growth of GDP, population, oil and CO_2 prices, globalisation or regionalisation, high or low (government) regulation, etc.

The scenarios developed within this study are built on four reference scenarios developed within the Eururalis project (2010). In Eururalis the four scenarios served as basis for the assessment of future changes in rural areas of Europe in relation to economy, land use and environmental impacts. In this study there was a need to allow for larger variation in specific policy measures and

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[2] Based on Lako et al. (2010) - Scenarios for the analysis of biomass chains for the EU countries and country regions in the timeframe 2010-2030.

technological development than specified in the Eururalis scenarios. Because of this it was decided to involve a larger range of variation in the regulation dimension of the four scenarios, and less in the global / regional paradigm determining the four Eururalis scenarios. Due to this decision, it proved to be sufficient to select only two contrasting scenarios out of the four original 'strategic orientation' scenarios, Global Economy (GE) and Regional Communities (RC), and to combine these with three levels of low, base, and high policy intervention. This resulted therefore, in six scenario-policy combinations. The assumptions made within the scenarios do not necessarily have to be true in reality. The objective is to outline extreme conditions, and to study what happens as a result of those conditions. Table 3 presents the basic assumptions for the two contrasting scenarios used in this study.

Table 3.
Basic assumptions for the two contrasting scenarios used in this study[3].

	Population	**Solidarity**	**Economy**	**Globalisation**	**Regulation**
A1 Global Economy	↗	↘	↗	↗	↘
B2 Regional Communities	↘	↗	↗	↘	↗

The Global Economy (GE) scenario has as its mission statement, that market-based solutions are the most efficient way to achieve strong economic growth and optimise demand and supply of goods, services and environmental quality. The oil price decreases from $70/barrel in 2010 to $65/barrel in 2020, and $60/barrel in 2030, whereas the price of CO_2 is assumed to decrease from € 25/ton CO_2 in 2010 to € 20/ton CO_2 in 2020, and € 15/ton CO_2 in 2030. The agricultural policy may vary from no to low governmental intervention. The demand for biomass remains rather modest compared to RC scenario. With regard to nature conservation and other sensitive areas some level of protection measures remain, depending on the policy intervention variant. Due to relatively higher technological development, it is more likely that higher yield levels are realised than in the RC scenario.

The Regional Communities (RC) scenario has as its mission statement that self-reliance, environmental stewardship and equity are the keys to sustainable development, and local communities being the cornerstones of society. The price of oil increases from $70/barrel in 2010 to $90/barrel in 2020, and $110/barrel in 2030, whereas the price of CO_2 increases from € 25/ton CO_2 in 2010 to € 37.5/ton CO_2 in 2020, and € 50/ton CO_2 in 2030. The agricultural policy may vary from low to high governmental intervention. These conditions are favourable for the production of biomass, but competition for land with agriculture and nature conservation is stiff. Legislation on nature conservation and other sensitive areas is generally strict but varies per policy intervention variant. The overall increases in yields are expected to be more limited, compared to GE scenario because of lower technological development.

The policy assumptions of the default variants of the two scenarios, namely, the 'base intervention' variant of the GE scenario, and the 'high intervention' variant of the RC scenario are presented in Table 4.

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[3] Based on: EUruralis, 2010.

Table 4.
Policy assumptions with regard to default variants of the GE and RC scenarios.

	Unit	Starting value	GE Scenario Base intervention		RC Scenario High intervention	
		2010	2020	2030	2020	2030
Agricultural policy						
Intervention (creation of demand and trade barriers)	[-]		No	No	High	High
Single Farm Payments (SFP): Increase in relation to 2005 situation. SFP are postal code specific	[%]	100%	40%	35%	180%	200%
Additional support to biomass crops	[€/ha/a]	0	25	25	120	150
Environmental policy						
RES support (electricity)	[%]	100%	70%	30%	150%	200%
RES support (electricity)	[€/GJ]	10	7	3	15	20
RES support bio-based products	[€/GJ]*	0	7	3	15	20
CO_2 credits	[%]	100%	40%	50%	200%	250%
Nature conservation / sustainability criteria	-		Low	Low	High	High
Technology						
Technological development	-		Medium	Medium	Medium	Medium
Yield increase (traditional use food/fodder crops)	[%/a]		1	1	0.5	0.5
Yield increase (food/fodder crops for bio-based application)	[%/a]		2	2	1	1
Yield increase (novel crop e.g. perennial bioenergy crop)	[%/a]		3	3	3	3

* Based on amount of fossil fuel (GJ) avoided.

2.4 Dutch biomass demand and supply in 2010-2030[4]

In December 2010 the Dutch government presented the Dutch National Renewable Energy Action Plan (NREAP) to the European Commission. In this report a binding target for renewable energy by 2020 was set of 14% of the total energy consumption. It is also set out how The Netherlands intends to fulfil this target. According to the NREAP 51% of this target is to be fulfilled by bioenergy. What is not clear however, is what the bioenergy mix will be both in terms of type, amount and conversion technology by 2020.

The main aim of this study is to present an estimation of the most likely mix of biomass feedstock that is needed in 2020 to fulfil the renewable energy target, including an extrapolation up to 2030. In this study we therefore present an analysis which tries to identify the main biomass sources under different scenario situations. It also provides an estimation of the spatial distribution of the main biomass sources contributing to the final 2020 renewable energy target.

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[4] Based on Mozaffarian et al. (2011) - Dutch biomass demand and supply in 2010-2030.

The GE and RC Scenarios described in the previous paragraph are used to further translate the 2020-2030 energy demand into a renewable energy and bioenergy demand. These contrasting scenarios are also applied to translate the types of biomass feedstock (as predicted to be available in The Netherlands by Koppejan et al. (2009) by 2020) into a final bioenergy supply mix that matches the total demand for bioenergy estimated. Finally, a presentation is given of how this biomass feedstock supply is spatially distributed over The Netherlands.

The assumptions concerning the Dutch primary and final energy consumption for the GE and RC Scenarios are summarised in Table 5. Also a summary of the Dutch biomass demand and supply in the GE and RC Scenarios is presented in Table 6 and Table 7. For comparison, also the expected biomass demand in 2020 according to NREAP (2010) is presented.

Table 5.
Primary and final energy consumption (PJ) in GE and RC Scenarios.

	2010	2020	2030
Primary energy consumption			
GE	3,300	3,630 (+10%)	3,795 (+15%)
RC	3,300	2,640 (-20%)	2,310 (-30%)
Final energy consumption			
GE	2,415	2,683	2,819
RC	2,415	2,296	2,097

In the GE Scenario due to a combination of, among others, high level of economic growth, low energy prices, low attention for energy saving measures, and inefficient use of by-products, both the primary and final energy consumption will increase, compared to the consumption levels in 2010. In the RC Scenario due to a combination of, among others, low level of economic growth, high energy prices, high attention for energy saving measures, and efficient use of by-products, both the primary and final energy consumption will decrease, compared to the consumption levels in 2010.

Biomass demand for the production of electricity and heat (BIO-E + BIO-H) in both scenarios are higher than the available Dutch biomass for these sectors according to Koppejan et al. (2009). Therefore, import of sustainably produced biomass will be required to fulfil the demand in these sectors.

Table 6.
Dutch biomass demand and supply in GE Scenario, including expected biomass demand according to NREAP (2010).

	2010	2020 NREAP	2020 GE	2030 GE
Biomass demand (PJ final energy)				
BIO-E	21	60	35	75
BIO-H	30	63	29	56
BIO-F (total (2nd gen.))	13	35	45 (6)	66 (17)
BIO-CHEM	?	?	14	36
Total	**64**	**158**	**123**	**233**
Biomass supply				
BIO-E & BIO-H, according to Koppejan *et al.*, 2009 (PJ final energy)	44	-	54	64*
BIO-E & BIO-H, BIO-F, BIO-CHEM, derived from Sanders *et al.*, 2006 (PJ primary energy)	-	-	125	250

* Based on extrapolation of the 2020 data

Table 7.
Dutch biomass demand and supply in RC Scenario, including expected biomass demand according to NREAP (2010).

	2010	2020 NREAP	2020 RC	2030 RC
Biomass demand (PJ final energy)				
BIO-E	21	60	72	128
BIO-H	30	63	70	114
BIO-F (total (2nd gen.))	13	35	49 (12)	70 (35)
BIO-CHEM	?	?	36	113
Total	**64**	**158**	**227**	**425**
Biomass supply				
BIO-E & BIO-H, according to Koppejan *et al.*, 2009 (PJ final energy)	44	-	94	114*
BIO-E & BIO-H, BIO-F, BIO-CHEM, derived from Sanders *et al.*, 2006 (PJ primary energy)	-	-	250	500

* Based on extrapolation of the 2020 data

A roadmap, based on the concept of biorefinery, has been developed by Sanders et al. (2006) for the sustainable production and development of biomass in The Netherlands up to 2030. The total Dutch biomass supply potentials assumed in this study are derived from the roadmap's total Dutch biomass potential in 2030. The assumed potentials for both the GE and RC Scenarios are quite high, and can fulfil a considerable fraction of the biomass demand in each sector of the both scenarios. However, still additional biomass needs to be imported in order to match the demand for biomass in both scenarios.

Based on the developed roadmap, the Dutch biomass streams to be used for the production of biofuels (BIO-F) are: used oil, grass, residues from food and stimulants industry, potato and beet crops, rapeseed, salt-tolerant grasses and other crops (cultivated on the Dutch coastal areas), and seaweed. The Dutch biomass streams to be used for the production of chemicals (BIO-CHEM) are: grass, residues of rapeseed and wheat processing, manure (urea for fertilizers, proteins for chemicals), potato and beet crops (N- or O-functionalized chemicals), salt-tolerant grasses and other crops (cultivated on the Dutch coastal areas), and seaweed.

Finally, the estimated Dutch biomass potential for primary, secondary, and tertiary biomass in 2020 for the two scenarios, GE and RC, is presented after a spatial distribution is made of all the different biomass categories using detailed spatial information on location of main feedstock sources in The Netherlands. Biomass feedstock is unevenly distributed over the Dutch territory. Every feedstock type has its main source. The territorial distribution of the different feedstock types was made in a GIS approach according to the following steps:

- define per biomass feedstock type what the main sources are;
- identify spatial data sources at the highest possible resolution providing information about the location of every specific feedstock source;
- map every feedstock data source in absolute number at the level of postal code area level 4 (PC4);
- use the intensity of the feedstock source (amount) per PC4 as a weighting factor to distribute/map the national total feedstock over all PC4 in The Netherlands;
- categorize the feedstock types and produce maps.

The biomass potential has been mapped for both the GE and RC scenarios according to the following categories:

1. primary biomass from agriculture;
2. primary woody biomass from forests and landscapes;
3. other primary biomass;
4. secondary biomass manure;
5. secondary biomass food and stimulants industry;
6. other secondary biomass;
7. tertiary biomass.

Figure 1 presents the final total biomass potential map of The Netherlands. The left hand map shows the potential for the Global Economy and the right hand map for the Regional Communities scenario, which has by far the largest potential. According to Figure 1, the best regions in The Netherlands to set up biomass feedstock chains are concentrated in eastern Brabant and northern Limburg, the centre of the country in Flevoland, and the North of Gelderland and Overijssel.

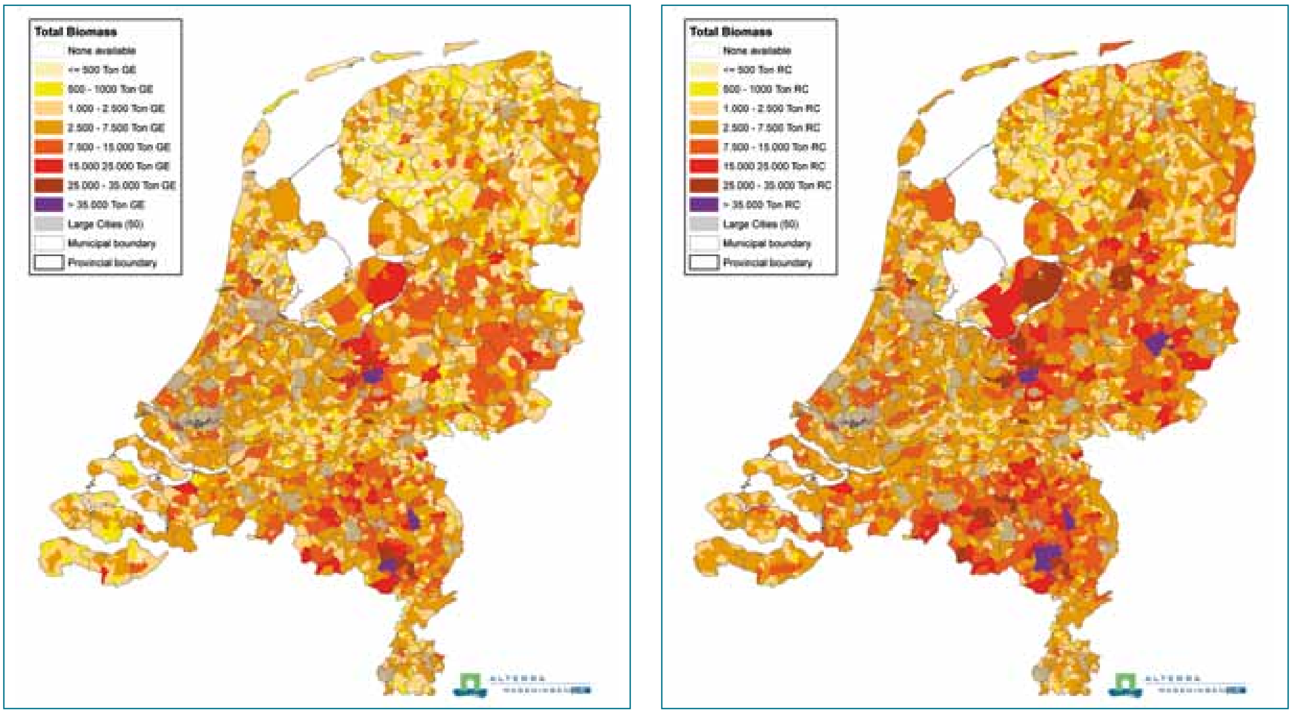

Figure 1.
Final total biomass supply potential map of the Netherlands (left: GE, right: RC).

2.5 European biomass resource potential and costs[5]

This paragraph summarises the outcomes of a study on the European (EU-27 and Ukraine) cost and supply potential for biomass resources. Three methodological steps were distinguished (i) an evaluation of the available 'surplus' land, (ii) a modelled productivity and (iii) an economic assessment for 13 typical bioenergy crops. Results indicate that the total available land for bioenergy crop production – following a 'food first' paradigm – could amount to 900,000 km^2 by 2030. Three scenarios were constructed that take into account different development directions and rates of change, mainly for the agricultural productivity of food production. Feedstock upply of dedicated bioenergy crop estimates (Figure 2) varies between 1.7 and 12.8 EJ y^{-1}. In addition, agricultural residues and forestry residues can potentially add to this 3.1–3.9 EJ y^{-1} and 1.4–5.4 EJ y^{-1} respectively. First generation feedstock supply is available at production costs of 5–15 € GJ^{-1} compared to 1.5–4.5 € GJ^{-1} for second generation feedstocks. Costs for agricultural residues are 1–7 € GJ^{-1} and forestry residues 2–4 € GJ^{-1}. Large variation exists in biomass production potential and costs between European regions, 280 (NUTS2) regions specified. Regions that stand out with respect to high potential and low costs are large parts of Poland, the Baltic States, Romania, Bulgaria and Ukraine. In Western Europe, France, Spain and Italy are moderately attractive following the low cost high potential criterion. Preconditions to develop the high production potential are that the agricultural practice in the CEEC is modernized, that lignocellulose crops for 2nd generation biofuels are commercialized and implemented on a larger scale and that significant residue streams are allocated to energy purposes.

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[5] Based on de Wit & Faaij (2010) - European biomass resources potential and costs.

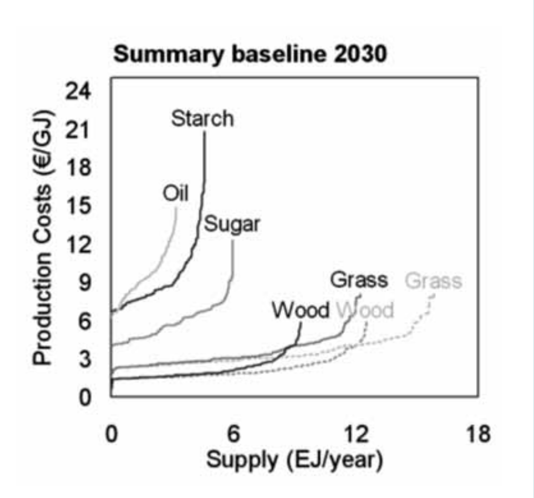

Figure 2.
Cost-supply curves for all crop groups for 2030 on arable land for the baseline scenario. The dotted curves for grass and wood indicate the supply potential on grassland.

2.6 Developments in European agriculture: relations to and opportunities for bioenergy[6]

This paragraph summarises a study that discusses if, how fast and to what maximum yield improvements can be realized in Europe in the coming decades and what the opportunities and relations are to biomass production. The starting point for the analysis is the historic context of developments in European agriculture over the past five decades. Historic developments in European crop and animal protein productivity between 1961 and 2007 show an average mean annual growth rate of 1.6%. In relative terms developments are slower on average in The Netherlands and France at 1.0% y^{-1} than in Poland and Ukraine (USSR) at 2.2% y^{-1}. In absolute figures, however, growth has been considerable in Western Europe and modest in the Central and Eastern Europe. Yield trends further show that significant yield changes can be realized over a short period of time. Positive growth rates of 3 to 5% y^{-1} were reached in several countries and for several crops in several decades. In Eastern European countries during their transition in the 1990s negative growth rates as low as -7% y^{-1} occurred. Outcomes suggest that productivity levels can be actively steered rather than being just the result of autonomous developments. Current yield gaps differ greatly between Western Europe (France <10%) and Central and Eastern Europe (Poland and Ukraine 50-60%). This suggests that yields in Central and Eastern Europe, with dedicated agricultural policy, may be able to catch-up with Western European levels. Ideally, such a dedicated policy follows a leap-frog approach, meaning that past experience form the starting point for future policy development. Western European countries have developed in the direction of maximum attainable levels. This is confirmed by stabilizing yield growth rates over the last two decades (Figure 3). Yield improvements in this region may come from breakthrough innovations. Projections for regional growth rates differ significantly in literature resulting in different outlooks for biomass production. At the extremes the European bioenergy potential, assuming average bioenergy crop yields, can amount to 5.1-9.3 EJ y^{-1}. High yielding lignocellulosic crops could double this potential. It is concluded that the potential to free-up agricultural lands for the production of bioenergy crops in Europe is considerable.

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[6] Based on de wit et al. (2011) - Productivity developments in European agriculture: Relations to and opportunities for biomass production.

The degree to and the pace at which yields develop will determine how much of the potential is opened up. Agricultural policy and technological development are key to open up the potential.

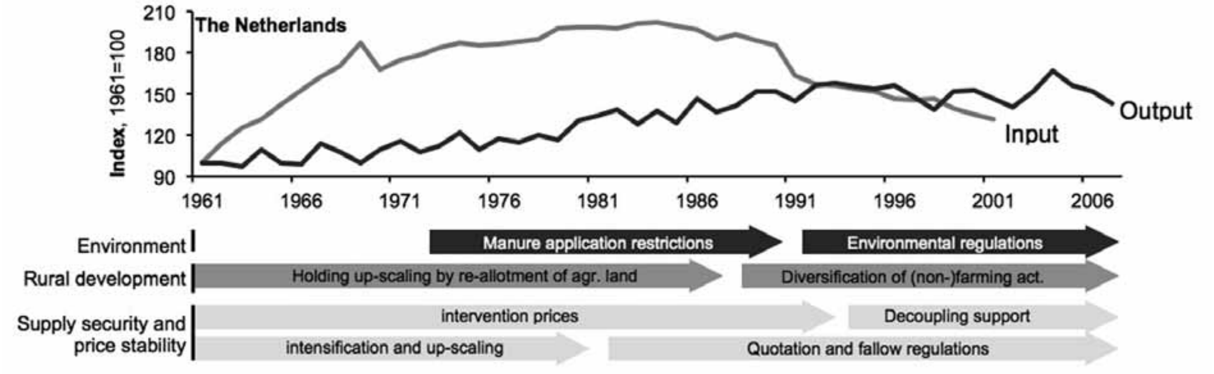

Figure 3.
The aggregated developments in agricultural crop productivity and resource inputs for the Netherlands for the period 1961-2007.

2.7 Competition between biofuels: modelling technological learning and cost reduction over time[7]

A key aspect in modelling the (future) competition between biofuels is the way in which production cost developments are computed. This paragraph reports on a study that was conducted with three objectives: (i) to construct a (endogenous) relation between cost development and cumulative production (ii) to implement technological learning based on both engineering study insights and an experience curve approach, and (iii) to investigate the impact of different technological learning assumptions on the market diffusion patterns of different biofuels. The analysis was executed with the European biofuel model BioTrans, which computes the least cost biofuel route. The model meets an increasing demand, reaching a 25% share of biofuels of the overall European transport fuel demand by 2030. Results (Figure 4-a) show that 1st generation biodiesel is the most cost competitive fuel, dominating the early market. With increasing demand, modestly productive oilseed crops become more expensive rapidly, providing opportunities for advanced biofuels to enter the market. While biodiesel supply typically remains steady until 2030, almost all additional yearly demands are delivered by advanced biofuels, supplying up to 60% of the market by 2030. Sensitivity analysis shows that (i) overall increasing investment costs (Figure 4-d) favour biodiesel production, (ii) separate gasoline and diesel subtargets (Figure 4-b) may diversify feedstock production and technology implementation, thus limiting the risk of failure and preventing lock-in and (iii) the moment of an advanced technology's commercial market introduction (Figure 4-c) determines, to a large degree, its future chances for increasing market share.

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[7] Based on de Wit et al. (2009) - Modelling Competition Between Biofuels: Modelling technological learning and cost reduction over time.

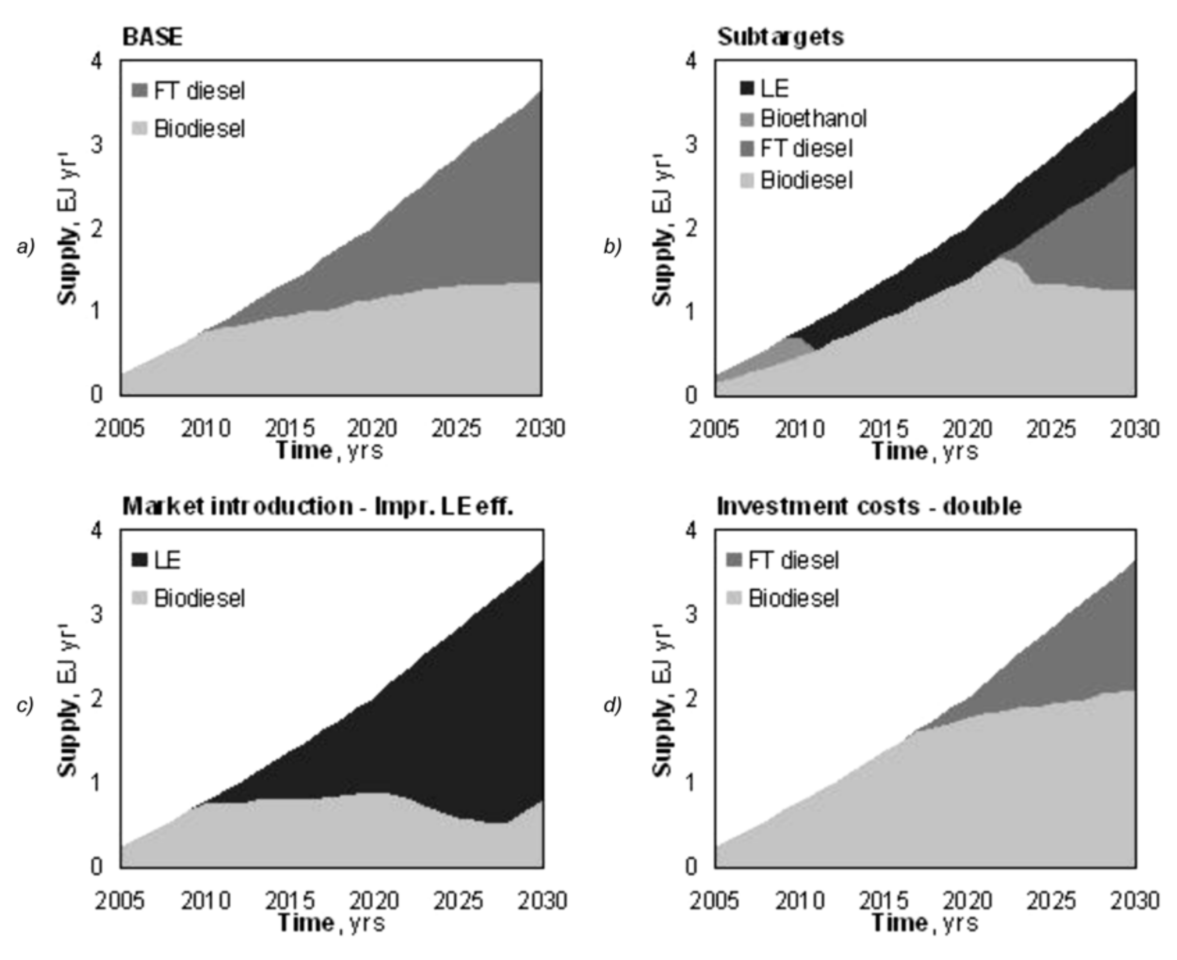

Figure 4.

Results of the least cost biofuel route analysis with the European biofuel model BioTrans. Indicated are the shares for bioethanol, biodiesel, lignocellulose ethanol (LE) and Fischer-Tropsch diesel (FT diesel).

2.8 Environmental impacts of integrating biomass production in European agriculture[8]

As energy crop production on European croplands expands, boosted by accelerating bioenergy use, there is a need to evaluate the environmental impacts associated with their production. On-going yield increases are considered to raise agricultural output without the need to convert nature and grasslands to additional cropland. The cumulative greenhouse gas emissions (GHG) of N_2O, net soil organic carbon fluxes and abated emissions from replacing fossil transport fuels by biofuels are evaluated for nine land use variants (Figure 5) with MITERRA-Europe. It is found that it is possible to combine large-scale biomass production, sustain current food production levels without (in)direct land use changes and accomplish significant net environmental benefits in European agriculture. Continuance of current agriculture results in 4.9 $GtCO_2$-eq. of cumulative N_2O emissions by 2030. Intensified food production and energy crop production on freed cropland can seriously reduce cumulative emissions for the annual crop groups oil, starch and sugar beet to 1.9, 1.5 and 2.1 $GtCO_2$-eq. respectively. Perennial energy crop production can mitigate cumulative emissions for grass and

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[8] Based on de Wit et al. (2011; submitted for publication) - Environmental impacts of integrating biomass production in European agriculture.

wood crops, respectively to 3.3 and 4.5 $GtCO_2$-eq. by 2030. Results suggest that research or policy efforts aimed at further increase of productivity raise the output from existing European cropland while at the same able to reduce or mitigate emissions.

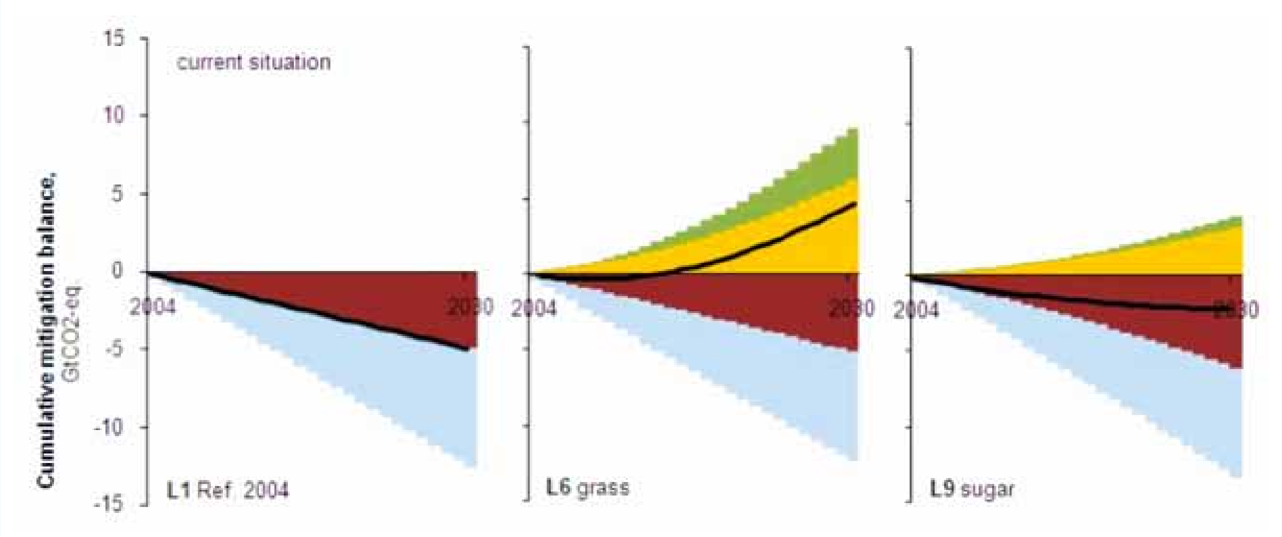

Figure 5.
Partitioning of the cumulative mitigation balance of greenhouse gasses in European agriculture from 2004 to 2030 (black line) for nine land use variants (L1-L9) evaluated, considering N_2O emissions (red), CH_4 emissions (blue, not considered in the net balance), net soil organic carbon sequestration (green) and fossil fuel abatement (yellow). Negative values indicate emissions, positive values indicate mitigations.

3. Integrated spatial design and assessment of regional biomass delivery chains: tools, models and approach

3.1 Introduction

In this Chapter a description is given of the different components of the integrated framework for biomass delivery chain assessment. Attention will especially focus on the tools, models and knowledge integrated in the framework and the links between the different components. The description in the different sub-sections will cover the different components. The final section describes the practical use of the integrated framework/tool.

First a more general overview is given of the function of the components in the whole framework, then a more detailed description is given of the knowledge, models and data used by focusing on a couple of biomass delivery chains which have already been assessed with the framework. A first overview of the framework is given in the Figure 6. It consists of four main modules.

In Module 1 *(Pre-defined data)* data are defined either by the user, or are already pre-defined in the framework (on biomass chains already assessed by the framework). These data are used as a starting point for design, spatial implementation and impact assessment of the biomass chain. They refer to three groups of pre-defined data: scenario characteristics, chain type characteristics and chain basics. In Section 3.2 (and the User manual of the framework) these groups will be further described, and it is explained how these data are used to come to a further chain specification.

Central in Module 2 *(Generation of national biomass potential maps)* is the Geographic Information System (GIS) based biomass potential calculator. This tool is fed with information from a map library with different biomass sources, cost and other data layers. It also contains an economic profitability model (based on Net Present Value logic) that is combining cost and profitability information with soil suitability into cost-supply information. These are all used to create technical-economic potential maps of biomass resources given in the specifications of Module 1. How the economic biomass potential is assessed is discussed in Section 3.3 of this Chapter. The map library and the GIS based biomass potential calculator are described further in Section 3.4. The biomass potential maps created in this module are the starting point for further chain design and impact assessment. Which maps are already contained in the present tool is also described in Section 3.4.

In Module 3 *(Chain specification)* the final biomass chain is specified using the general specifications chosen by the user in Module 1 and the technical-economic biomass potential maps from Module 2. A central interactive tool in this module is the design and specification of the logistical and technical organization of the chain. With the biomass cost and distance calculator it is further determined which part of the biomass potentials derived from Module 2 is used by the chain and which transport costs are involved for collecting the required biomass, the pre-treatment and the conversion into a final product (e.g. bioenergy, biofuels or chemicals). How this chain specification exactly works is further explained in Section 3.2 and the User manual of the framework).

The final Module 4 *(Impact assessments)* covers the impact assessment of the total chain as designed and spatially implemented in the former three modules. The impacts assessed include the economic performance of the chain (Section 3.6), the GHG performance and the land based environmental impacts (Section 3.5).

There are also several non-quantifiable criteria and effects connected to biomass delivery chains. These criteria have not (yet) been included into the current version of the framework but need to be taken into account when setting up a chain. They are discussed in Section 3.7 of this Chapter.

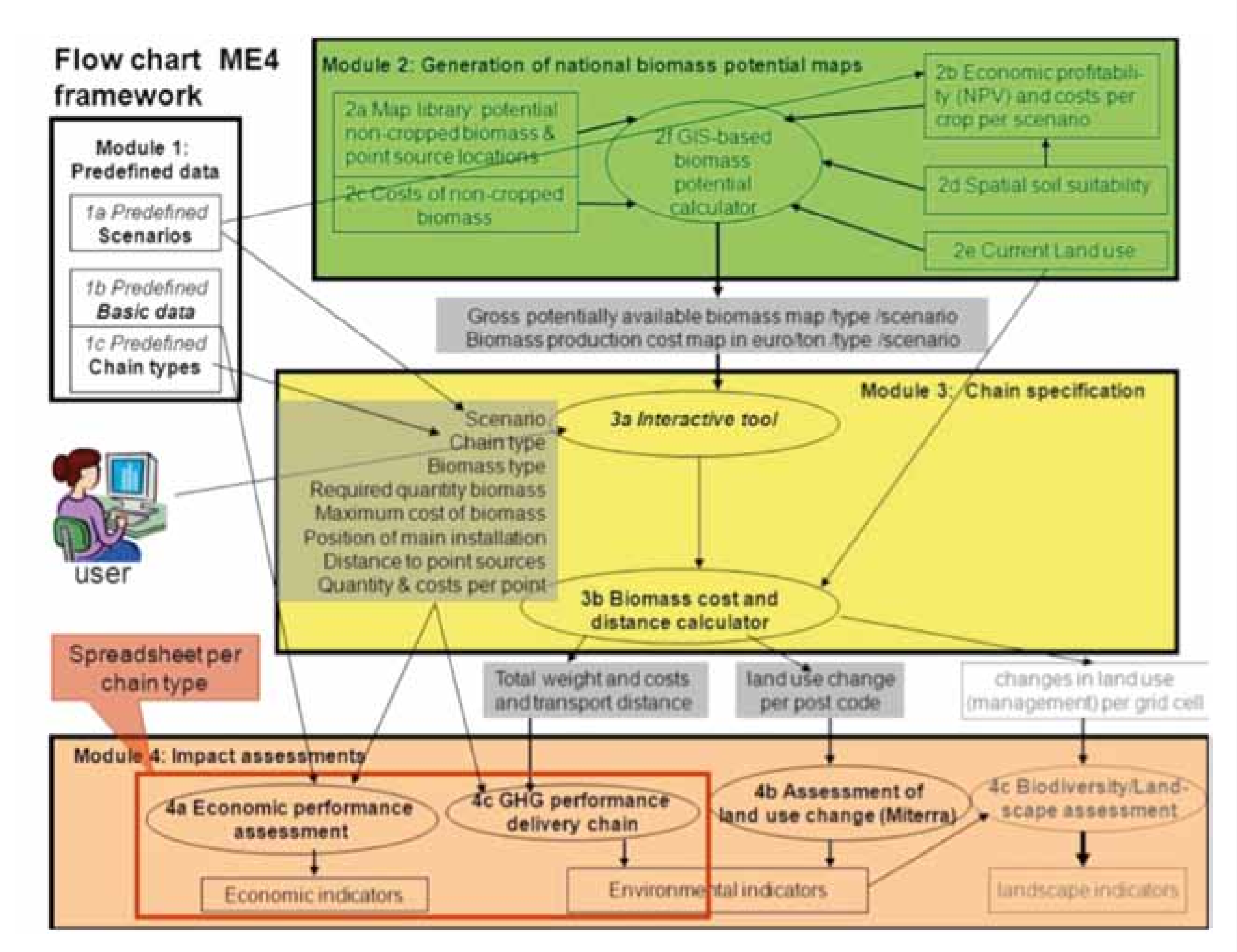

Figure 6.
Schematic overview of the framework for the integrated spatial design and assessment of regional biomass delivery chains.

Section 3.8 finalises with a description of the practical use of the integrated framework. The User Manual of the framework contains a more detailed description of the way the current framework interacts with the user.

3.2 Chain design

In the current version of the framework biomass chains need to be designed according to three dimensions of information, specified in three steps. This sets the basis for further spatial implementation and analysis of a biomass delivery chain.

In the first step a scenario (see Section 2.3) context needs to be chosen within which the biomass chain is designed and assessed. By specifying the scenario context, a choice is made for a set of exogenous factors which have an important influence on the technical, political, economic and social context within which the biomass delivery chain will need to operate. In the current tool the Present Situation (PS) and two major future scenarios are identified: Global Economy (GE) and Regional Communities (RC). Both scenarios have three policy variants: low, basic and high intervention (see Section 2.3). These scenarios provide a set of exogenous parameters that is used in the further design, spatial implementation and assessment of the biomass delivery chain. The user may also choose to specify a scenario himself. This can be done by adapting (a selection of) the existing scenario parameters according to his own judgements. The main scenario parameters include oil price, CO_2 price, specifications on technological development, economic growth etc. For more details on the scenario specifications see the User Manual.

The second dimension of information to be specified in the second step refers to basic characteristics of the chain. This includes the conversion process and end-product (e.g. electricity, heat, through combustion or gasification, etc.) and the size of the installation.

In the third step a whole range of choices needs to be made such as the location of main conversion installation(s), the proportion of biomass to be used for bioenergy, (with the option to also exclude areas from where biomass feedstock cannot be derived), the possible use of point sources from where large quantities of biomass can be obtained (e.g. harbours), and maximum costs of biomass).

In the current version of the framework biomass is derived from the area located in a circle around the conversion installation. In practice this will not be the only biomass extraction area. Usually large quantities of biomass are also derived from point sources like harbours or industrial areas. The integration of point sources in the model has not been fully implemented in the current version but is planned in the near future.

It should also be mentioned that the present framework can only design simple chain types consisting of a biomass extraction area and one central conversion location. In the near future the framework will be further adapted to design more complex multi-nodal chains where in some nodes pre-treatment and storing of biomass is done and in one or more nodes in other locations conversion to energy and other products takes place. Such a more complex chain is more realistic and will certainly become more common once the concept of bio-cascading becomes a reality.

3.3 Economic viability of regional biomass production: Net Present Value (NPV)

The competitiveness of non-food biomass crops is assessed by calculating the biomass production costs and the production costs of the final products (e.g. bioenergy or bioethanol), and by then comparing the Net Present Value (NPV). The NPV is the Present Value of future income minus the costs. The NPV method enables the comparison of the value of different cash crops over a long period of time. With this method a value comparison can be made between rotational arable crops which deliver a harvest one or more times a year and perennial crops which start to deliver return only after a couple of years while most costs for establishing a plantation need to be made in the first year. The time horizon is assumed to be the same as the rotation length of the perennial crop (20 years). The discount rate used reflects interest rates of a combination of long- and short-term loans (Houtsma, 2008).

Calculations of NPV have also been made for different scenarios (as described is Section 2.3). Several scenario specific factors influence the NPV values of which the most important are oil price which influences the price of diesel for mechanisation but also of fertilisers, labour costs, policy interference and technical development.

The NPV is calculated in a separate NPV-model (van der Hilst et al., 2010). In the present framework this NPV-model is used to calculate the feedstock production and the production costs for the most common arable rotations in The Netherlands, separate rotational arable crops and perennials like Miscanthus and willow for the current situation and the scenarios. The costs related to crop production generally include four main categories of expenses:

- land costs;
- field operation costs (contractor, machinery, labour and diesel costs);
- input costs (seeds, fertilizers and pesticides);
- fixed costs (insurance, soil sample assessment, etc.).

The benefits of crop production are the revenue from:

- selling the main product;
- selling the co-product;
- CAP subsidies for crop production.

The NPV-model is spatially explicit which implies that the values per crop and rotation are calculated taking account of detailed spatial circumstances like land use and suitability. The current land use, and the soil suitability for both current crops and potential biomass crops are mapped using a Geographical Information System (GIS) at a resolution of 100 meters. For the feedstock production and costs calculations included in the framework, the soil suitability is taken into account for seven soil suitability classes (see Table 8). The link between soil suitability class and the Dutch soil map is based on the work of Brouwer & Huinink (2002) and van Bakel (2007).

Table 8.
Classification soil suitability as function of yield reduction due to water and drought stress.

Suitability classification	Yield reduction
very suitable	0-10%
high suitable	10-20%
suitable	20-30%
medium suitable	30-40%
low suitable	40-60%
marginally suitable	60-80%
very marginally suitable	80-100%

Yield statistics provided by LEI CBS (2007) and de Wolf & van der Klooster (2006) were used to make correct estimates of yield levels for the whole of The Netherlands, differentiated according to sand and clay soils. These average yield levels were translated to yield levels per suitability class by taking the relative share of suitability class per crop for current land use into account.

This step resulted in two maps (per biomass type): one of the yields and one of the production costs of the potential biomass within the Netherlands. In the present framework both maps can be used to choose a suitable location for the installation and to identify the final locations of dedicated cropping. Both are discussed in Section 3.4.

3.4 Biomass potentials and land use change effects

In Section 3.3 it was explained how the economic biomass potential of dedicated crops was assessed. This resulted in maps (covering the whole of The Netherlands) of potential biomass quantities and production costs. These maps can be used to pinpoint a suitable location for the installation of biomass conversion plants by the user. The next step is to determine which part of the potential will finally be harvested and what the land use change implications are.

In order to do this a calculation module is contained in the framework that computes in several iterations what radius is required to “harvest” the required amount of biomass for the selected chain within a circle around the installation, and what the production and transport costs (to the installation) of the harvested biomass will be.

Before the iteration process is started several criteria can be taken into account. Firstly, a maximum price level needs to be specified by the end user above which biomass cannot be purchased for inclusion in the chain. This maximum should be matched with the mapped cost-supply information available for the required biomass feedstock type.

Secondly, it is possible to specify which proportion of the available biomass can be purchased from every grid cell (ranging from 0-100%). The lower this proportion the larger the radius around the installation becomes until costs become too high to make it economically feasible to harvest as costs increase with transport distance.

Thirdly, it is possible to specify maps with areas that must be excluded from harvesting (e.g. a future expansion of a town). These exclusion criteria can be included in the process provided a map of the excluded area is included in the map library of the framework.

Once all these are specified the iteration process is run and this results in a final solution. This solution specifies how much biomass is harvested from every grid cell and thus which part of the available utilised agricultural area is used for dedicated cropping of a certain biomass crop. The GIS module in the framework then generates a new land use map incorporating the new dedicated cropping areas. This results in a new land use situation which can then be compared to the present land use situation to determine the land use changes as is further describe in Section 3.8.3 under ‘Function impacts assessment’. Comparison of both maps is also done in a GIS module of the framework which then generates the land use changes. These land use changes are the basis for environmental impact assessment of the chain (see Section 3.5).

3.5 Land based environmental impacts of regional biomass chains

The interactions between a biomass supply chain and the regional conditions have a strong influence on the actual environmental and socio-economic performance of biomass chains. As the spatial variation in determining parameters of impacts of biomass chains is significant, impacts should preferably be assessed spatially explicitly. The GIS module in the framework provides spatially explicit information on present land uses and new land uses resulting from a biomass conversion chain implementation as discussed above. The changes in land use and in the related management are then the start of the environmental impact assessment.
The Miterra model (Lesschen et al., 2009; van der Hilst et al., submitted) is used to assess the environmental impacts of biomass production at postal zone level. Miterra simulates the N and P balance, emissions of NH_3, N_2O, NO_X, and CH_4, leaching of NO_3 and changes in soil and biomass carbon stocks (Figure 7). The main input data of the model are crop areas, derived from the Basic Registration of Parcels (BRP) database, and livestock numbers, derived from the Geographical Information system Agrarian Businesses (GIAB), at postal code level. Crop yields were obtained at province level from the CBS (‘oogstraming’ data).

The Miterra model follows the methodology proposed in the IPCC (2006) guidelines to calculate the GHG emissions due to the cropping of a biomass crop and the land use change related emissions (LUC). GHG emissions due to LUC are caused by changes in soil and biomass carbon stocks. In addition, LUC affects N_2O emission due to changes in fertilizer and manure application and drainage of organic soils. As it is assumed that there are no changes in livestock, livestock related N_2O and CH_4 emissions are assumed to remain constant when land is converted to energy crops. Within the framework tool the following outputs are included: GHG emission from fertilizer production, CO_2 emission from fuel use, GHG emission from cultivation (soil N_2O emission + CO_2 from peat soils), CO_2 emission from changes in soil organic carbon (SOC), total GHG emission from agriculture (including livestock), N soil surplus, P soil surplus, NO_3 concentration in leaching water, NH_3 emission from agriculture and SOC stock (upper 30 cm).

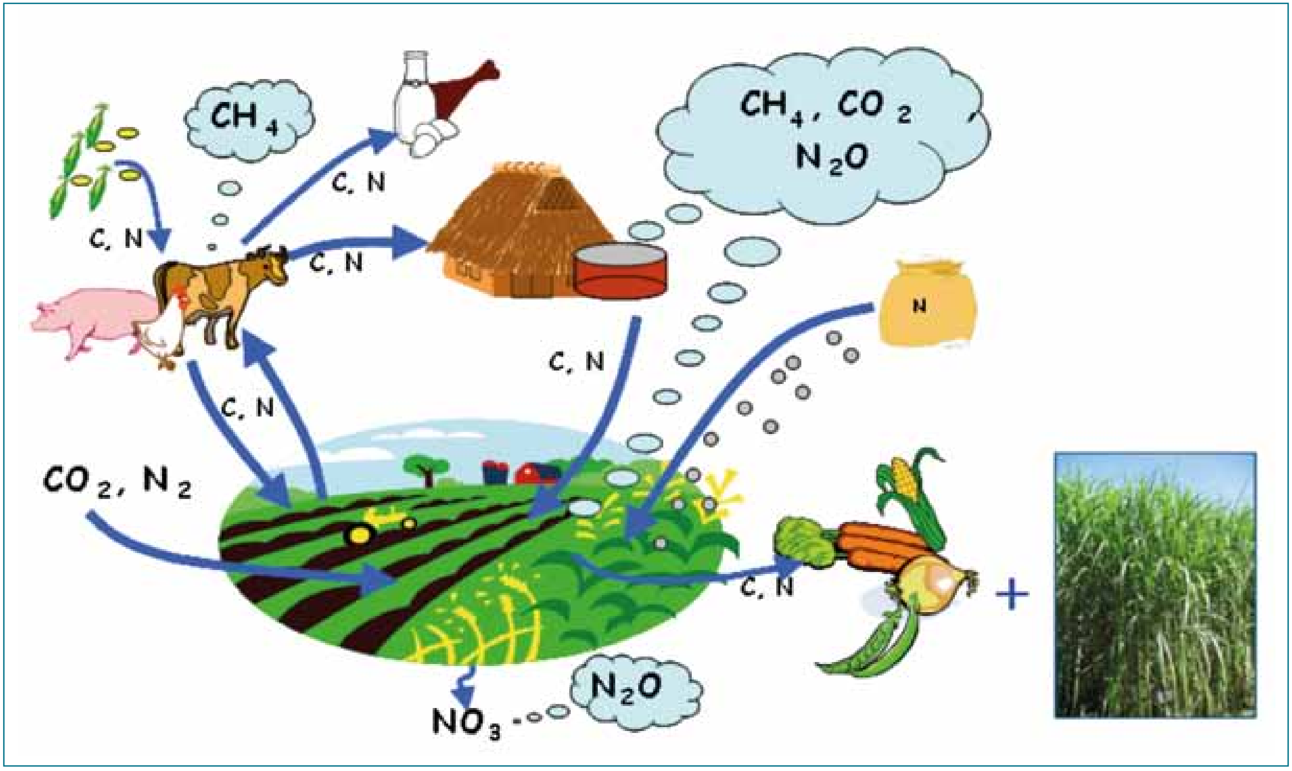

Figure 7.
Schematic overview of all GHG sources and flows included in Miterra.

For changes in SOC the default IPCC stock change factors were applied in combination with region specific SOC reference stocks. In line with IPCC (2006) a time horizon of 20 years is assumed to reach a new equilibrium after LUC. N_2O soil emissions consist of direct N_2O emissions from managed soils related to different N sources (manure, grazing, mineral fertilizer, crop residues and cultivation of organic soils) and indirect N_2O emissions due to N leaching and N deposition. N leaching is calculated by multiplying the N surplus with a leaching fraction derived from Fraters et al. (2007). Soil nutrient surpluses are calculated from the total nutrient input (manure, mineral fertilizer, deposition and N fixation) minus the removal by harvested crop products.

The amount of fuel (diesel) used per crop is calculated based on the field operations data as used in the NPV calculations (Section 3.3). The CO_2 emission is calculated by multiplying the amount of diesel by the CO_2 emission factor of 2.71 kg CO_2 per litre diesel. The average GHG emission for fertilizer production is calculated based on data of Brentrup & Palliere (2008), which result in the following emissions factors: 1.36 kg CO_2-eq/kg N for urea, 5.38 kg CO_2-eq/kg N for other N fertilizer and 3.55 kg CO_2-eq/kg P. For the 2020 scenarios it is assumed that the best available technique (BAT) would be standard: 1.13 kg CO_2-eq/kg N for urea, 4.21 kg CO_2-eq/kg N for other N fertilizer and 3.55 kg CO_2-eq/kg P.

For 2020 the amount of applied fertilizer is calculated according to balanced fertilization. Balanced N fertilization provides fertilizer and manure according to the crop N demand, after accounting for N inputs via atmospheric deposition, mineralization, and biological N2 fixation. Crop N demand is calculated as the total N content of the crop (= harvested part + crop residue) times an uptake factor. This uptake factor is set at 1.0 for grass and perennial energy crops and 1.1 and 1.25 for respectively cereals and other arable crops. A detailed description of balanced N fertilization is provided in Velthof et al. (2009).

All environmental impacts calculated in the MITERRA module are presented at an aggregate level for the whole chain but can also be presented at a spatially explicit level in maps in which comparisons can be made with the current land use situation to present the changes in emissions.

3.6 Economic and logistical performance assessment

In order to make a final evaluation of the chain performance indicators are produced on the economic and GHG impacts of the whole chain. Beside the land based environmental impacts, as discussed in Section 3.5, performance of the downstream part of the chain also needs to be included in the evaluation. For this a simple excel based model scheme was devised. For each chain type a separate excel sheet must be included in the framework, following the same scheme. This model (excel sheet) calculates the underneath parameters mentioned in Table 9.

Table 9.
Calculated parameters in economic and logistical analysis.

Data group	Parameter
Output simple chain calculation	calculation number
	biomass chain name
	scenario name
	scenario policy variant
	scenario year
Total throughput [ton dm]	from sources
Revenues and costs [euro]	heat revenues
	electricity revenues
	purchase costs
	storage costs
	transport costs
	loading/unloading costs
	pre-treatment costs
	drying costs
	conversion costs
Energy returns and use [GJ]:	heat returns
	electricity returns
	energy used for purchase
	energy used for storage
	energy used for transport
	energy used for loading/unloading
	energy used for pre-treatment
	energy used for drying
	energy used for conversion
GreenHouse Gas avoided and	heat GHG avoided
emission [ton CO_2-equivalents]	electricity GHG avoided
	GHG emission for purchase
	GHG emission for storage
	GHG emission for transport
	GHG emission for loading/unloading
	GHG emission for pre-treatment
	GHG emission for drying
	GHG emission for conversion

With the above parameters the final performance indicators of the chain are calculated. The total cost and revenues are added up and subtracted to calculate the final profit as is illustrated in Section 3.8.3 (Figure 12).

As to the total GHG performance of the chain a calculation is made of the total emissions and the total GHG emissions avoided. The combination of both enables the calculation of the mitigation potential. An illustration of how this is calculated for the sugar beet case is provided in Section 3.8.3 (Figure 14).

3.7 The influence of social criteria[9]

3.7.1 Introduction

Bioenergy production is suffering from a relative lack of knowledge development, when compared to other renewable technologies like wind and solar energy. There are many reasons for this, diversity of bioenergy chains and the often ambiguous attitude towards its contribution to a sustainable energy production being two of the most important ones (Bakker, 1997). While the basic public attitude until recently generally was positive, the food versus fuel debate has led to a more hold back attitude towards bioenergy and biofuels development. Apart from this, bioenergy chain development is also suffering from the general Not-In-My-Back-Yard (NIMBY) syndrome: unwillingness to put up with any nuisances (noise, odour, landscape changes) caused by bioenergy installations near homes or residences. A number of these nuisances, often treated in legislation and permit procedures, can be quantified in clear-cut calculation-rules. Other aspects are more of a non-quantifiable nature, offering a challenge. Speeding up bioenergy chain development could benefit in this respect from an open and transparent information supply to nearby inhabitants, while – more generally – effective stakeholder involvement processes could be profitable for successful chain development.

3.7.2 Decision support systems

Many tools exist, to support decision making in complex situations, often with contrary issues. Facilitating spatial and social decision making, for example, can profit from many models and methodologies (Herwijnen et al., 2002; IVM, 2010). The accent often is on modelling. Weighing of non-quantifiable issues can be either done in a pragmatic way by researchers, or using extensive procedures for participative consensus-based stakeholder decision processes. Participative processes are receiving increasing attention, especially in issues of general interest on a higher abstraction level (f.i. 'sustainable development on a national level'). On a project or local level, such methodologies might be too heavy an instrument to be used. Therefore, in this study we have developed a more direct pragmatic methodology that is easier to apply to a concrete project.

Processes developed in decision support systems demonstrate that the role of stakeholders in developing a bio-energy project is very important. Possible nuisances (e.g. noise or odour), should be determined beforehand, and criteria and weighing them should be straightforward and transparent. Complex or fuzzy methodologies should be avoided, as they draw strong attention to the tool itself and may lead away from the core of the issue: the lack of interaction with stakeholders that are directly involved.

Within the project, a stakeholder process approach was developed including the following steps: (i) identifying relevant stakeholders, (ii) project description, (iii) assessing the general attitude towards bio-energy and bio-energy projects in the near environment of the planned project, (iv) listing issues to be discussed ('nuisance factors' including noise, transport movements, odour etc. as well as 'rewarding factors' such as positive environmental effects, jobs provided, etc.), (v) determining calculation rules for quantitative criteria, (vi) organising a participative stakeholder workshop to discuss qualitative issues and to list criteria and weighing factors. For the weighing, a five point ranking is suggested, where (1) is negligible and (5) is severe. The purpose of the workshop is to discuss different alternatives for the bio-energy chain under consideration. Depending on the situation this might be an interactive process.

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[9] Based on Kalf et al. (2011) - Manual for dealing with non-technical aspects in bio-energy project development.

3.7.3 Summary

An outline has been developed for a stakeholder's participation and communication process for streamlining the process of the development of a bioenergy project initiative. The process gives calculation rules, for quantitative social criteria and describes a stakeholder process for qualitative criteria. The calculation rules for quantitative criteria are incorporated into the framework. The stakeholder process, is described in a manual, which is also integrated into the framework as an informative accompanying text.

3.8 Description of integrated framework for biomass delivery chain design and evaluation

3.8.1 Introduction

This section describes the practical use of the framework. Section 3.8.2 outlines the scope of the current framework. Section 3.8.3 describes the main functionalities, following the "tabs in the upper bar of the tool". Section 3.8.4 discusses technical aspects of the current tool. A detailed description of the way the present framework interacts with the user can be found in the User Manual.

3.8.2 Scope of the current framework

An important goal of the project was to develop an integrated framework to be used to assess the spatial, environmental (including ecology and landscape) and socio-economic performance of biomass delivery chains at different geographical levels.

During the project we focussed on developing a simple and flexible interactive tool, containing a limited set of scenarios, chain types and economic and environmental indicators that should mainly be considered as examples. The framework has been implemented in such a way that it is relatively easy to adapt (e.g. add scenarios, chain types and indicators), although this must be done by a team of experts in the field of bioenergy and software development.

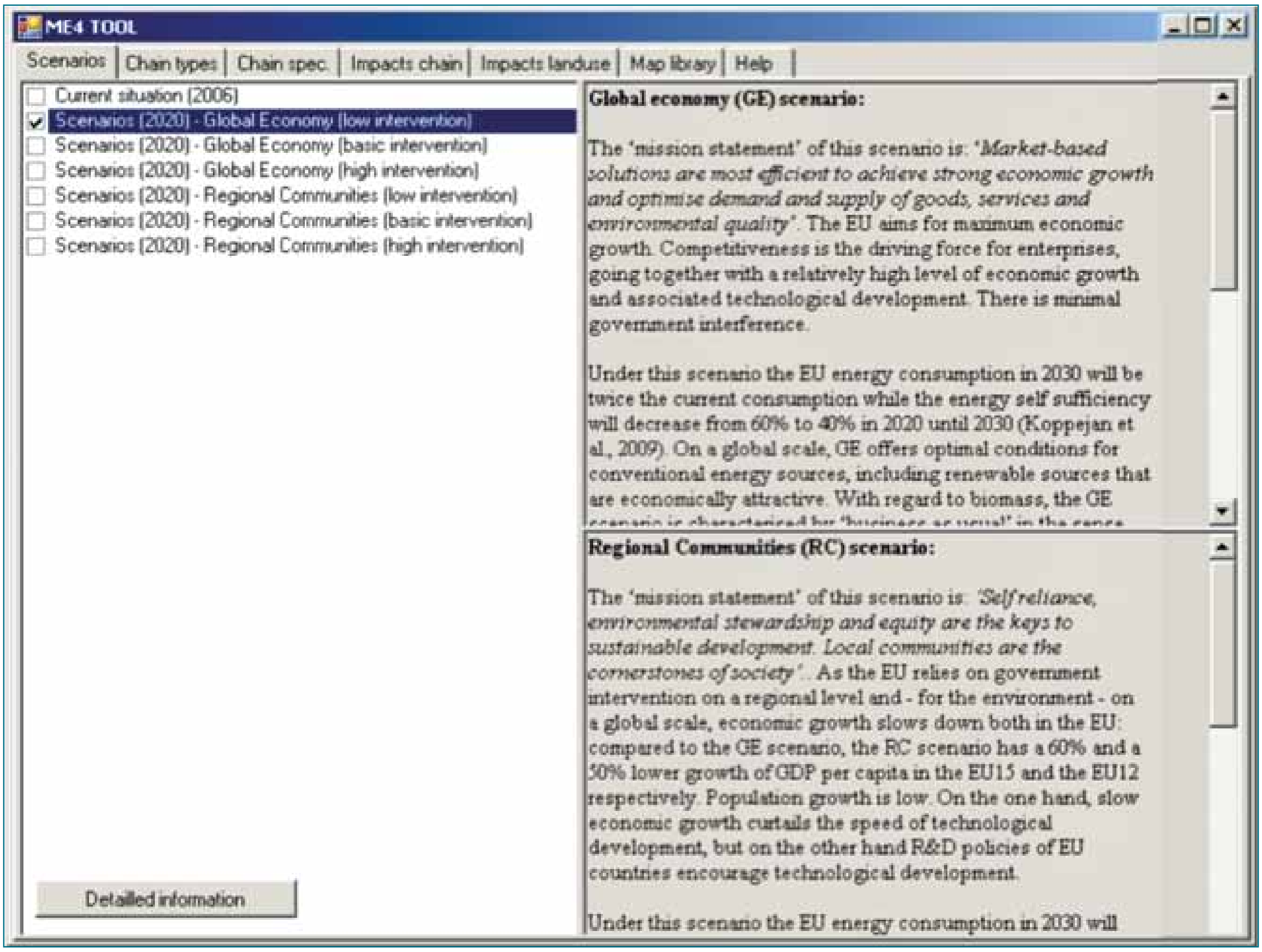
The current framework allows to rapidly design and assess the economic and environmental performance of a bioenergy chain, by selecting a pre-defined scenario, chain type and biomass type, and by choosing a location for the bioenergy, biofuel or biorefinery installation. The framework computes where the required amount of biomass for the specified chain might be harvested (near the chosen location), and calculates the production costs of the required biomass. Next the costs and revenues of the different components of the specified biomass chain can be computed, as well as the avoided and used amount of energy, and the Green House Gas balance of the chain. If the specified biomass chain implies that current crops will be (partly) replaced by (other) biomass types, the impacts on the environment due to this land use change will be computed as well. The results may vary per scenario, due to differences in input parameter values related to different presumed economic, technical and political conditions (see Section 2.3). Although scenario parameter values are given for 2020 and 2030, in the current framework only the impacts in 2020 are calculated and compared with the current situation (2010).

The current framework is restricted for use within The Netherlands and contains only a limited set of scenarios, chain types and biomass types. As mentioned before, these should be considered as examples. For the use in practice it will usually be necessary to add scenarios and other chain and biomass types. This also implies that new input data such as quantities and cost maps of new biomass types might have to be made. So, although no special knowledge is required to use the current demonstration tool, experts on bioenergy chains and on the used software will be required to adapt the tool for use in "real" situations.

3.8.3 Main functionalities

The main functionalities of the framework can best be described by explaining the different tabs in the upper bar of the tool:

Function Scenarios: offers information on pre-defined scenarios and enables the user to select a scenario (see Figure 8). The tool displays a description of the scenarios and allows to view the parameter values per scenario that are used in the framework. In the current framework two major scenarios are identified: Global Economy (GE) and Regional Communities (RC). Both scenarios have three policy variants: low, basic and high intervention (see Section 2.3).



☐ Current situation (2006)
☑ Scenarios (2020) - Global Economy (low intervention)
☐ Scenarios (2020) - Global Economy (basic intervention)
☐ Scenarios (2020) - Global Economy (high intervention)
☐ Scenarios (2020) - Regional Communities (low intervention)
☐ Scenarios (2020) - Regional Communities (basic intervention)
☐ Scenarios (2020) - Regional Communities (high intervention)

Global economy (GE) scenario:

The 'mission statement' of this scenario is: '*Market-based solutions are most efficient to achieve strong economic growth and optimise demand and supply of goods, services and environmental quality*'. The EU aims for maximum economic growth. Competitiveness is the driving force for enterprises, going together with a relatively high level of economic growth and associated technological development. There is minimal government interference.

Under this scenario the EU energy consumption in 2030 will be twice the current consumption while the energy self sufficiency will decrease from 60% to 40% in 2020 until 2030 (Koppejan et al., 2009). On a global scale, GE offers optimal conditions for conventional energy sources, including renewable sources that are economically attractive. With regard to biomass, the GE

Regional Communities (RC) scenario:

The 'mission statement' of this scenario is: '*Self reliance, environmental stewardship and equity are the keys to sustainable development. Local communities are the cornerstones of society*'.. As the EU relies on government intervention on a regional level and - for the environment - on a global scale, economic growth slows down both in the EU: compared to the GE scenario, the RC scenario has a 60% and a 50% lower growth of GDP per capita in the EU15 and the EU12 respectively. Population growth is low. On the one hand, slow economic growth curtails the speed of technological development, but on the other hand R&D policies of EU countries encourage technological development.

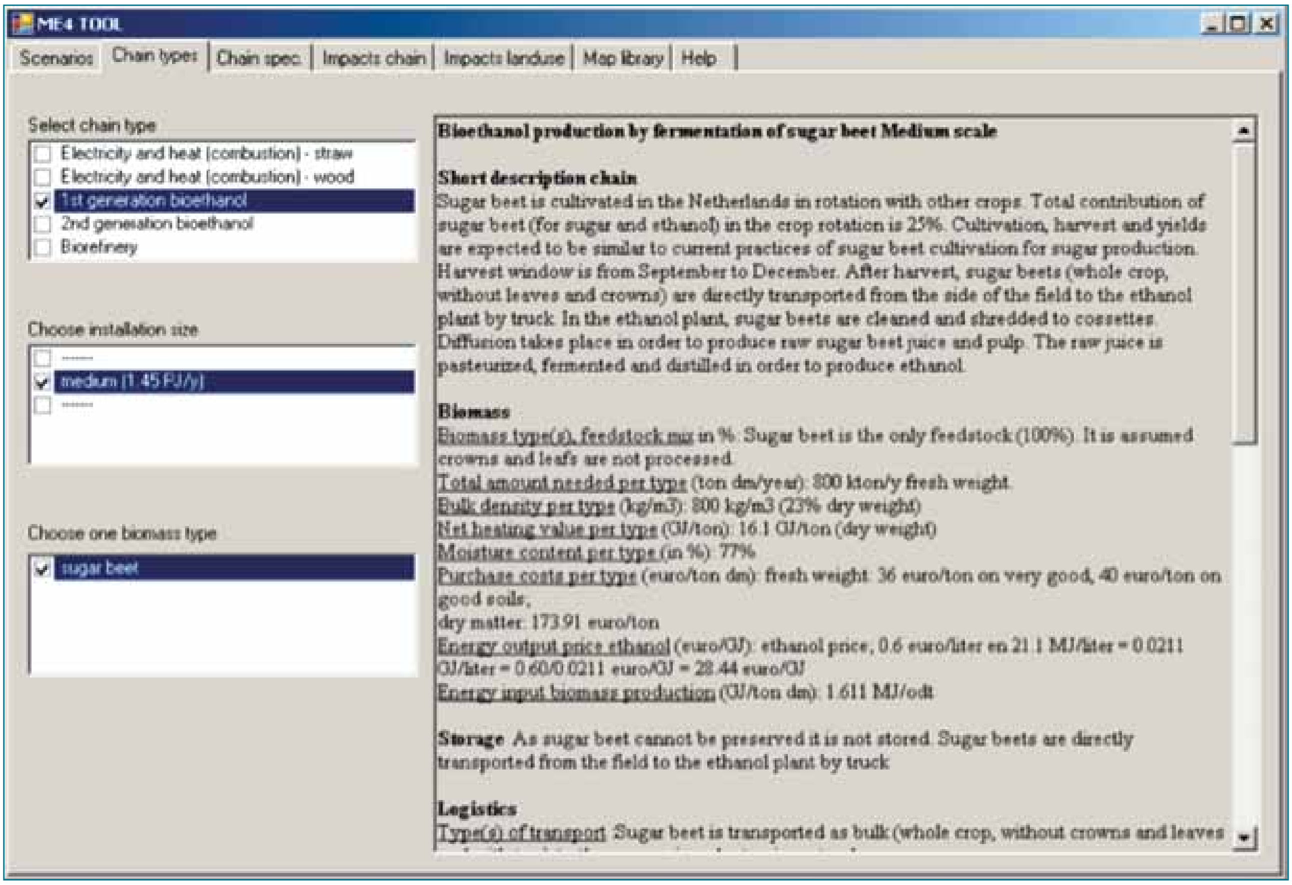
Under this scenario the EU energy consumption in 2030 will

Figure 8.
Example of scenario specification.

Function Chain types: offers detailed information on pre-defined biomass chain types (including the parameter values that are used for the assessments), and enables to select a chain type, size and biomass type(s). In the current framework the following biomass chain types are implemented:

- electricity and heat (combustion), small scale with straw as biomass (see Figure 9);
- electricity and heat (combustion + pelletizing), small scale with wood as biomass (only partly implemented);
- bioethanol 1st generation, medium scale with sugar beets as biomass;
- bioethanol 2nd generation, medium scale with Miscanthus as biomass.

The biorefinery chain type is not implemented in the current tool yet.



Select chain type

☐ Electricity and heat (combustion) - straw
☐ Electricity and heat (combustion) - wood
☑ 1st generation bioethanol
☐ 2nd generation bioethanol
☐ Biorefinery

Choose installation size

☐ --------
☑ medium (1.45 PJ/y)
☐ --------

Choose one biomass type

☑ sugar beet

Bioethanol production by fermentation of sugar beet Medium scale

Short description chain
Sugar beet is cultivated in the Netherlands in rotation with other crops. Total contribution of sugar beet (for sugar and ethanol) in the crop rotation is 25%. Cultivation, harvest and yields are expected to be similar to current practices of sugar beet cultivation for sugar production. Harvest window is from September to December. After harvest, sugar beets (whole crop, without leaves and crowns) are directly transported from the side of the field to the ethanol plant by truck. In the ethanol plant, sugar beets are cleaned and shredded to cossettes. Diffusion takes place in order to produce raw sugar beet juice and pulp. The raw juice is pasteurized, fermented and distilled in order to produce ethanol.

Biomass
Biomass type(s), feedstock mix in %: Sugar beet is the only feedstock (100%). It is assumed crowns and leafs are not processed.
Total amount needed per type (ton dm/year): 800 kton/y fresh weight.
Bulk density per type (kg/m3): 800 kg/m3 (23% dry weight)
Net heating value per type (GJ/ton): 16.1 GJ/ton (dry weight)
Moisture content per type (in %): 77%
Purchase costs per type (euro/ton dm): fresh weight: 36 euro/ton on very good, 40 euro/ton on good soils,
dry matter: 173.91 euro/ton
Energy output price ethanol (euro/GJ): ethanol price, 0.6 euro/liter en 21.1 MJ/liter = 0.0211 GJ/liter = 0.60/0.0211 euro/GJ = 28.44 euro/GJ
Energy input biomass production (GJ/ton dm): 1.611 MJ/odt

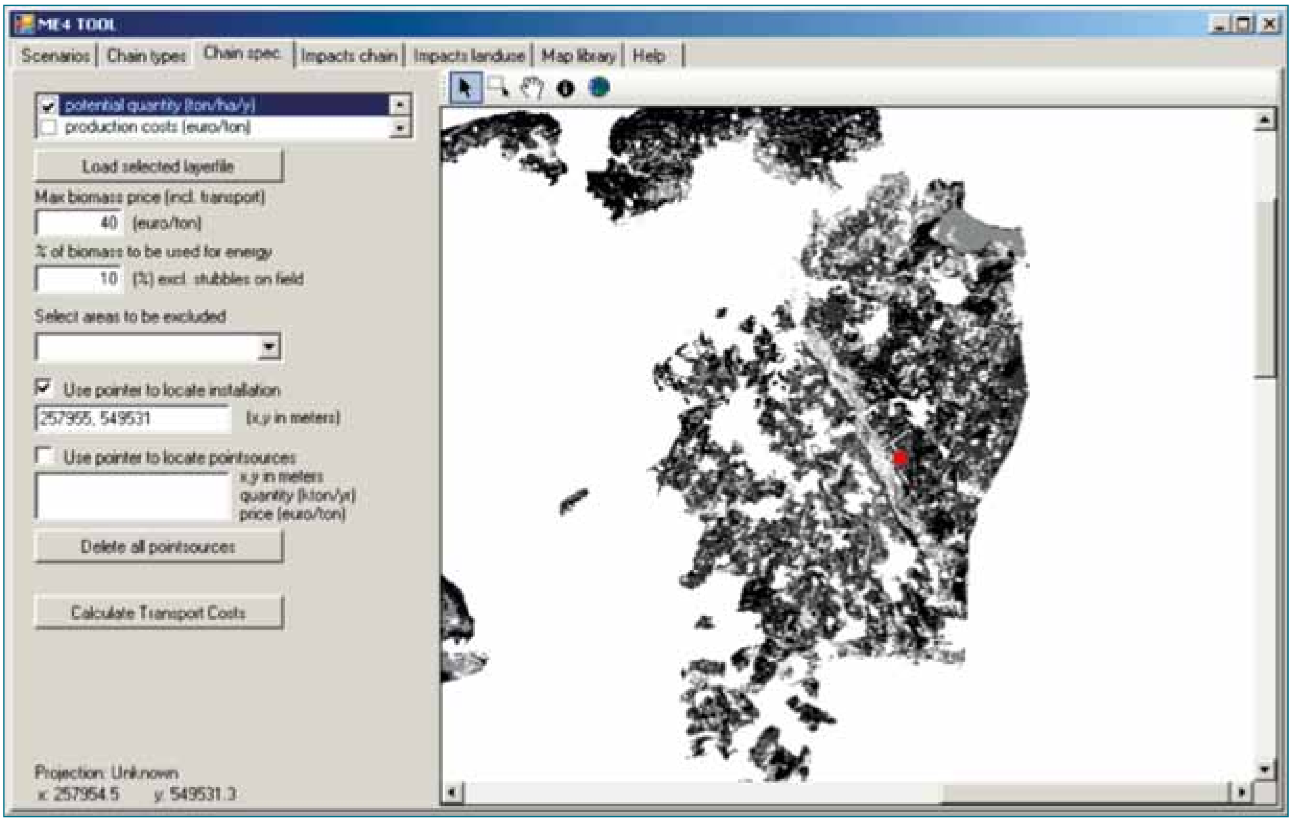
Storage As sugar beet cannot be preserved it is not stored. Sugar beets are directly transported from the field to the ethanol plant by truck.

Logistics
Type(s) of transport: Sugar beet is transported as bulk (whole crop, without crowns and leaves

Figure 9.
Example 1st generation bioethanol

Function Chain specification: enables to specify the biomass chain. The user can select a location for the energy installation and (optionally) locations of point-sources for biomass (like harbours) by pin-pointing the location on a map (see Figure 10). The user can also specify the maximum production costs of the biomass to be harvested, the percentage of the available harvested biomass that will be used for bioenergy, and the amount of biomass that will be purchased from each point-source. It is also possible to select a map with areas that must be excluded from harvesting (e.g. a future expansion of a town or a nature reserve area). This exclusion map must be provided by the end user in the correct format. When the biomass chain has been specified, the user can start the calculation of costs and distances: in several iterations the framework computes what radius is required to “harvest” the required amount of biomass for the selected chain within a circle around the installation, and what the production costs of the harvested biomass will be. It also identifies in which postal zones the biomass is harvested (required for the evaluation of the environmental impacts due to land use change).

When the biomass chain has been specified, the user can start the calculation of costs and distances: in several iterations (see Figure 11) the framework computes what radius is required to "harvest" the required amount of biomass for the selected chain within a circle around the installation, and what the production costs of the harvested biomass will be. It also identifies in which postal zones the biomass is harvested (required for the evaluation of the environmental impacts due to land use change).



☑ potential quantity (ton/ha/y)
☐ production costs (euro/ton)

Max biomass price (incl. transport)
40 (euro/ton)

% of biomass to be used for energy
10 (%) excl. stubbles on field

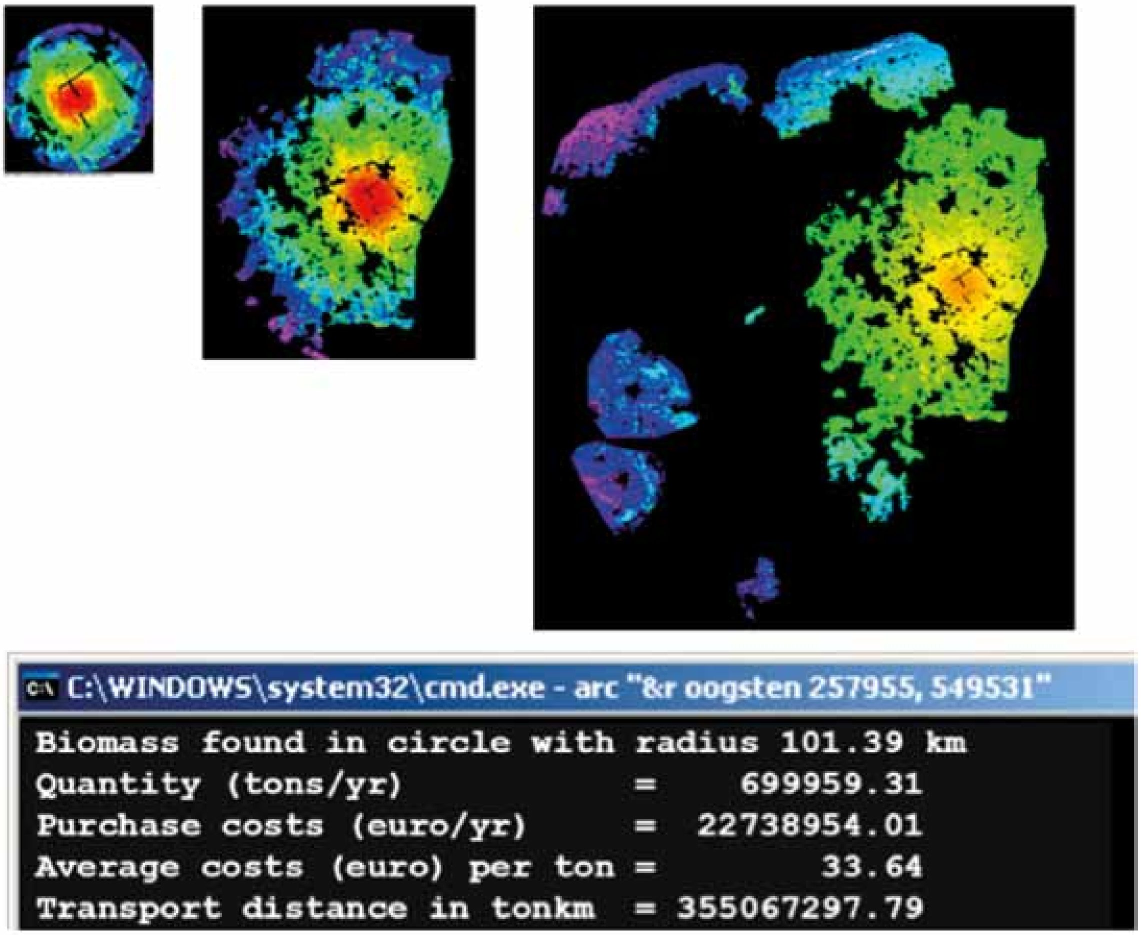
Select areas to be excluded

☑ Use pointer to locate installation
257955, 549531 (x,y in meters)

☐ Use pointer to locate pointsources
x,y in meters
quantity (kton/yr)
price (euro/ton)

Projection: Unknown
x: 257954.5 y: 549531.3

Figure 10.
Example of pin-pointing a location during the chain specification.

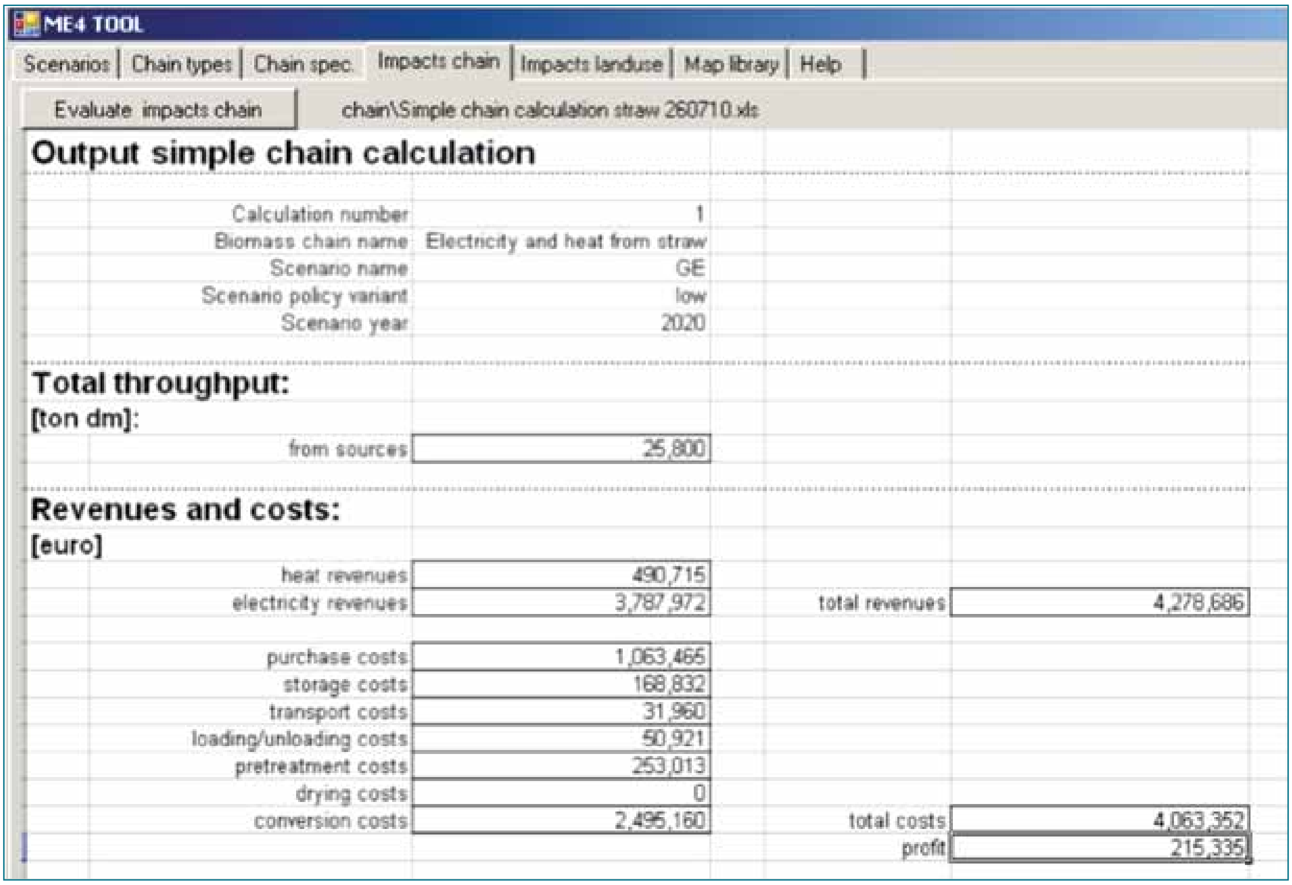


```
Biomass found in circle with radius 101.39 km
Quantity (tons/yr)              =     699959.31
Purchase costs (euro/yr)        =   22738954.01
Average costs (euro) per ton =            33.64
Transport distance in tonkm     = 355067297.79
```

Figure 11.
Example of the iterative calculation of costs and distances.

The coloured maps in Figure 11 are the (invisible) steps in defining the radius around the installation within which sufficient biomass from the biomass availability grid can be collected. First the biomass quantity (max biomass price and % used for bioenergy -input by the user- taken into account) within a circle of 10 km around the installation is determined (1). Based on the biomass demand of the installation and the average biomass density in the first circle a 2nd concentric circle is constructed (2). The biomass availability in the 2nd circle is determined, and by iteratively resizing the radius of the circle around the installation, an approximate radius is found within which the required biomass quantity for the installation is available (3).

Function Impacts chain: enables to evaluate the economic and environmental performance of the biomass chain (see also section 3.6). The economic performance is calculated by subtracting the total costs of the chain from the total revenues from the produced energy (in euros). If the result is positive the chain is expected to be profitable. The total costs are the sum of the costs of the different chain components and may include e.g. costs for purchase, storage, transport, pre-treatment and conversion of the biomass (See Figure 12).



chain\Simple chain calculation straw 260710.xls

Output simple chain calculation

Calculation number	1
Biomass chain name	Electricity and heat from straw
Scenario name	GE
Scenario policy variant	low
Scenario year	2020

Total throughput:
[ton dm]:

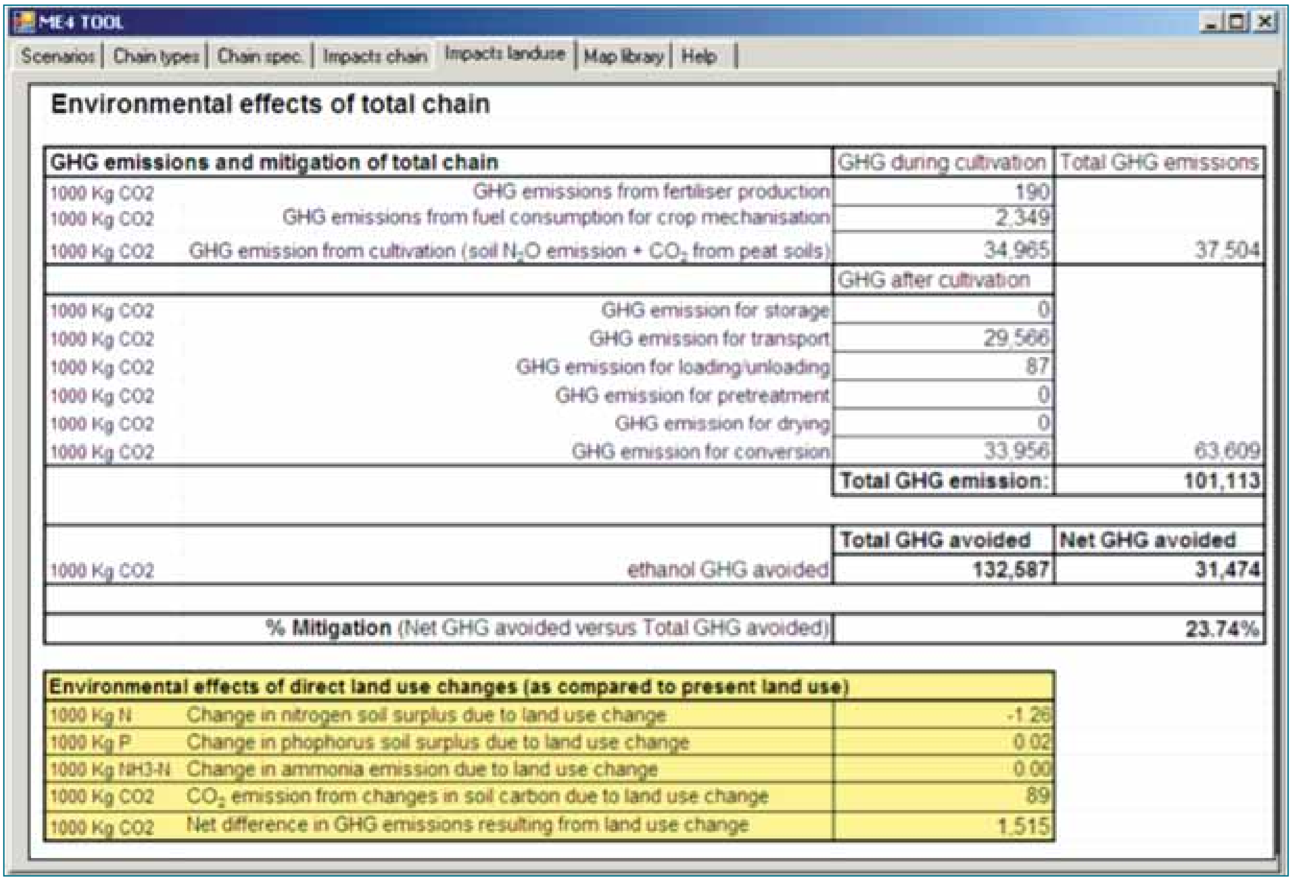
from sources	25,800

Revenues and costs:
[euro]

heat revenues	490,715		
electricity revenues	3,787,972	total revenues	4,278,686
purchase costs	1,063,465		
storage costs	168,832		
transport costs	31,960		
loading/unloading costs	50,921		
pretreatment costs	253,013		
drying costs	0		
conversion costs	2,495,160	total costs	4,063,352
		profit	215,335

Figure 12.
Example of a calculation with of simple chain calcualtion model.

The environmental performance of the chain is presented through different indicators (see Figure 13). Direct GHG emissions of the chain are calculated which consists of the land based emissions from the cultivation of the feedstock (in case of a biomass crop) and the emissions of the rest of the chain from transport, storage, pre-treatment, drying and conversion. The net amount of avoided Green House Gas (in ton CO_2 equivalents) is calculated by subtracting the total GHG emission of the chain from the calculated total amount of avoided GHG emission. In addition to the direct emissions and mitigation there are also emissions caused by a direct land use change coming from the demand for biomass and relate to emissions of GHG, nitrogen, phosphorus and ammonia emissions and these are also depicted in the lower part of Figure 13.



Environmental effects of total chain

GHG emissions and mitigation of total chain		GHG during cultivation	Total GHG emissions
1000 Kg CO2	GHG emissions from fertiliser production	190	
1000 Kg CO2	GHG emissions from fuel consumption for crop mechanisation	2,349	
1000 Kg CO2	GHG emission from cultivation (soil N_2O emission + CO_2 from peat soils)	34,965	37,504
		GHG after cultivation	
1000 Kg CO2	GHG emission for storage	0	
1000 Kg CO2	GHG emission for transport	29,566	
1000 Kg CO2	GHG emission for loading/unloading	87	
1000 Kg CO2	GHG emission for pretreatment	0	
1000 Kg CO2	GHG emission for drying	0	
1000 Kg CO2	GHG emission for conversion	33,956	63,609
		Total GHG emission:	**101,113**
		Total GHG avoided	**Net GHG avoided**
1000 Kg CO2	ethanol GHG avoided	**132,587**	**31,474**
	% Mitigation (Net GHG avoided versus Total GHG avoided)		**23.74%**

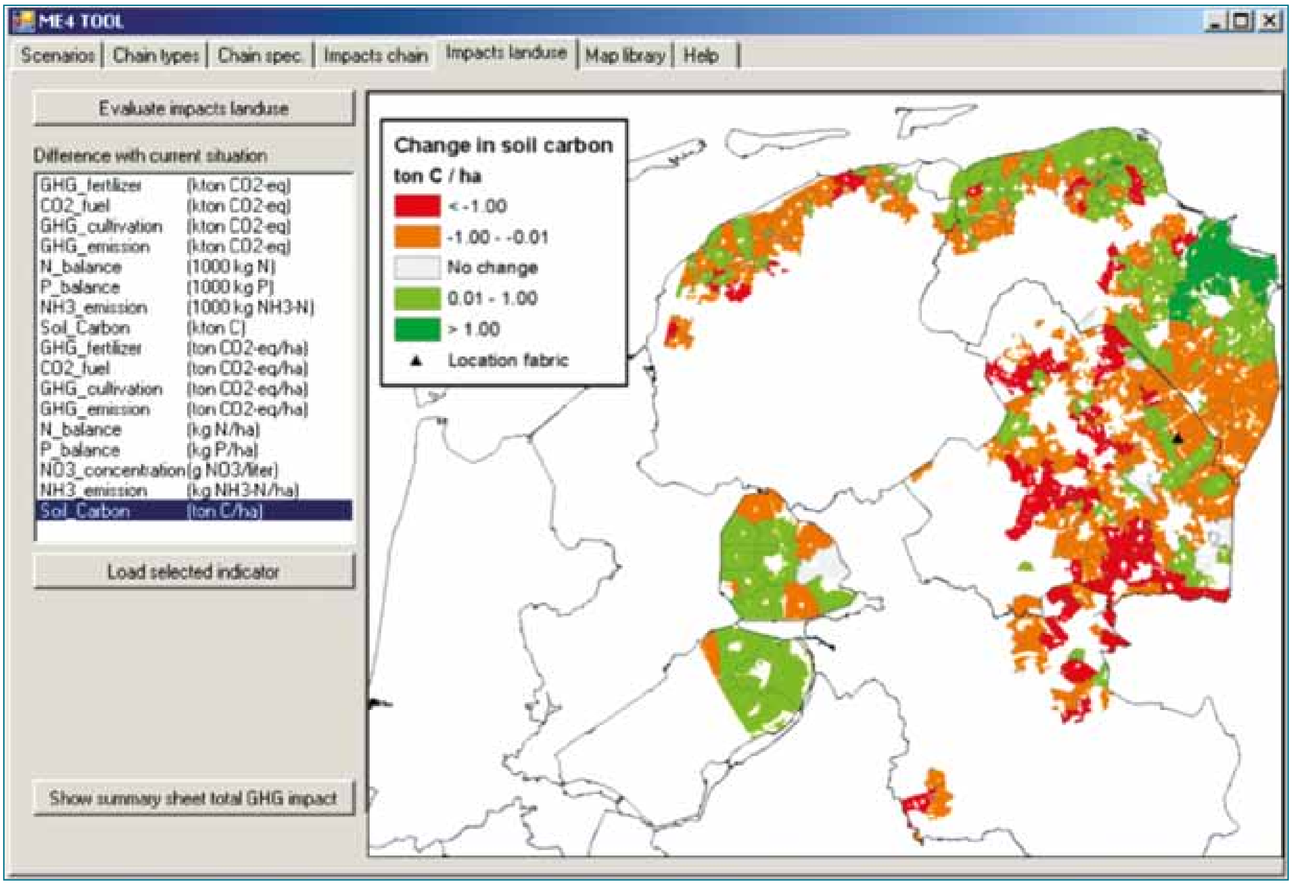
Environmental effects of direct land use changes (as compared to present land use)		
1000 Kg N	Change in nitrogen soil surplus due to land use change	-1.26
1000 Kg P	Change in phophorus soil surplus due to land use change	0.02
1000 Kg NH3-N	Change in ammonia emission due to land use change	0.00
1000 Kg CO2	CO_2 emission from changes in soil carbon due to land use change	89
1000 Kg CO2	Net difference in GHG emissions resulting from land use change	1,515

Figure 13.
Example of the calculation of the environmental effects of the total chain.

Beside the environmental effects the energy returns and energy use of the different chain components are calculated (in GJ). The results can be viewed in the tool, but are also stored in an excel sheet that contains the calculations as well, thus giving the means to get insight in the way the results have been calculated.

Function Impacts land use: enables to evaluate the spatial/environmental impacts due to land use changes. In the former in Figure 13 an overview was already given of the indicators calculated from the land use, the cropping, and the land use changes. Here it is explained in detail how this assessment works This evaluation is only relevant if current crops are replaced by other crops for bioenergy purposes. In the current framework this is the case in the bioethanol chain types. In the first generation sugar beet chain it is assumed that the current rotation of 10-15% sugar beets will be augmented to 25%, replacing in part other crops in the current rotations (like potatoes). In the second generation chain it is assumed that Miscanthus will replace 25% of the current arable crops in the area surrounding the conversion installation.

The Miterra model (Lesschen et al., 2009) is used to calculate – in advance – these impacts per postal zone for the whole of The Netherlands for all the bioethanol 1st and 2nd generation – scenario combinations. The output consists of (changes in) GHG, CO_2 and ammonia emissions, nitrate concentration in leaching water, nitrogen and phosphorus soil surplus, and soil organic carbon stock of the biomass production process. During a session, the framework selects and sums only the Miterra results of the postal zones in which the biomass has been “harvested” around the installation of the specified chain.



Difference with current situation

GHG_fertilizer	(kton CO2-eq)
CO2_fuel	(kton CO2-eq)
GHG_cultivation	(kton CO2-eq)
GHG_emission	(kton CO2-eq)
N_balance	(1000 kg N)
P_balance	(1000 kg P)
NH3_emission	(1000 kg NH3-N)
Soil_Carbon	(kton C)
GHG_fertilizer	(ton CO2-eq/ha)
CO2_fuel	(ton CO2-eq/ha)
GHG_cultivation	(ton CO2-eq/ha)
GHG_emission	(ton CO2-eq/ha)
N_balance	(kg N/ha)
P_balance	(kg P/ha)
NO3_concentration	(g NO3/liter)
NH3_emission	(kg NH3-N/ha)
Soil_Carbon	(ton C/ha)

Figure 14.
Example of an evaluation with Miterra.

The results per postal zone can be viewed in the tool on maps (see Figure 14) that show the increase or decrease of each indicator compared to the current situation (2006/2007). The tool also sums the impacts of all relevant postal zones for the selected chain (See Figure 13). The summed changes in GHG emissions due to direct land use change for the specified chain are stored in a GHG summary Excel sheet, together with the GHG emissions of the chain components, in order to calculate the net avoided emission of GHG of the total chain, including the land use change. In addition there are also impacts of the chain presented in relation to emissions of nitrogen, phosphorus and ammonia. This Excel sheet can be accessed and viewed from within the tool or viewed independently in Excel.

Function Map library: enables to view all the maps that are used as input - including e.g. soil suitability maps that are used to compute the potential amount of biomass -, and to store and view the maps that are generated while using the tool. The map library can be accessed from within the tool, but can also be used independent of the framework tool (See Figure 15).

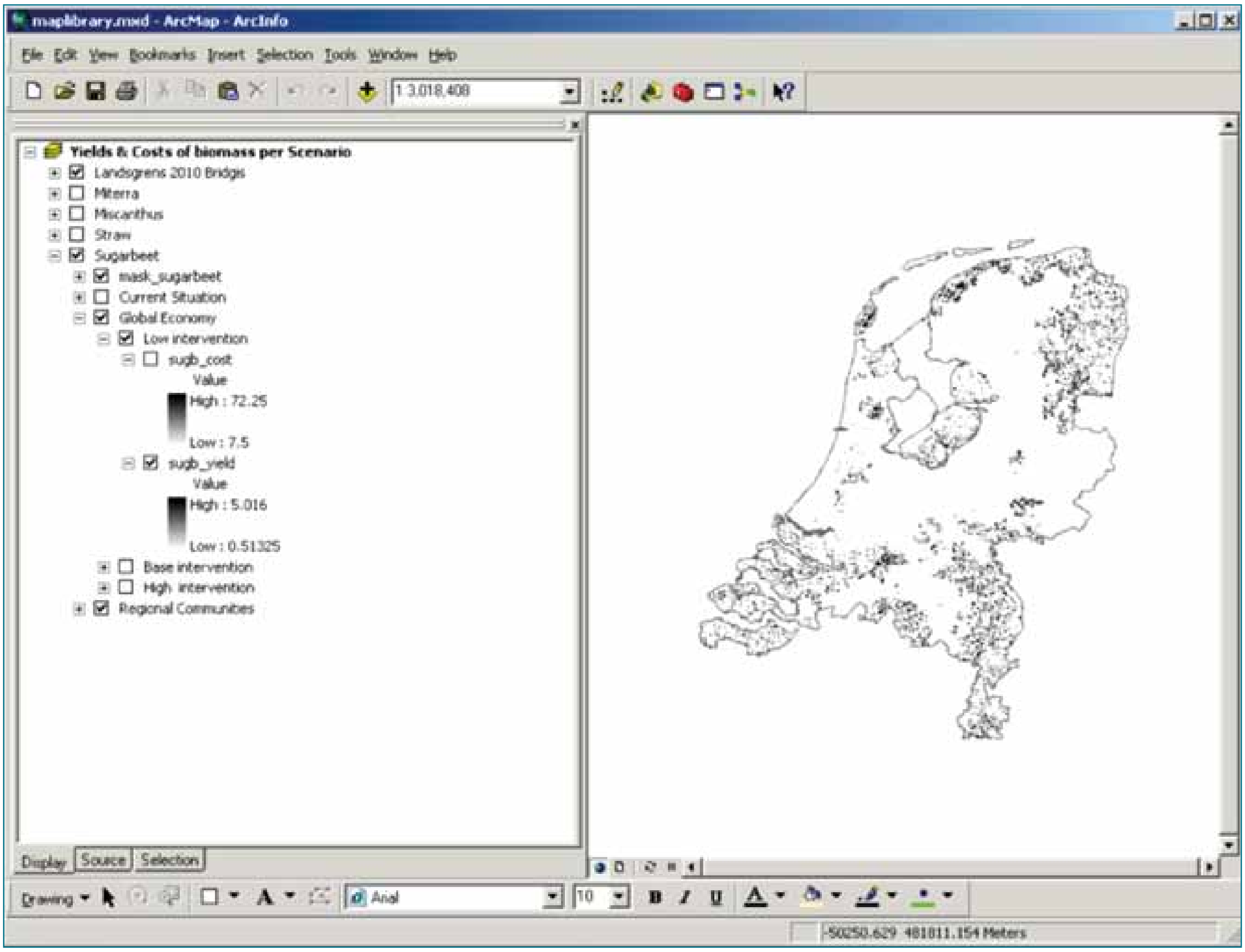


Figure 15.
Example of the map library.

Function Help: contains a user manual for the current framework, and a guideline for stakeholder (including citizens) involvement in the planning process of bioenergy installations (see Section 3.7). The user manual contains detailed information on the interaction with the user and the operation of the tool.

3.8.4 Technical implementation

The current framework is implemented in Visual Basic, using ArcInfo workstation for the execution of grid map operations (cell size 100x100m), an ArcGis MapComponent to display maps, and Excel for a flexible user interface, for data exchange with the NPV-model and Miterra, and for numerical calculations. For each biomass chain type a separate Excel sheet is created that calculates the economic and environmental performance of the chain. Excel can also be used independently to view the results and to compare results of different sessions with the framework tool.

The ArcMap application of Esri (part of the ArcGIS software package) is used to store and view maps in the map table. ArcMAP can be accessed from the framework, but runs as an independent application, and can also be accessed outside the framework tool.

The NPV model (see Section 3.3) is an independent Excel application used to calculate – in advance – economic and environmental parameter values per scenario that are used as input for the chain assessments.

The Miterra model (implemented in the GAMS modelling environment) is used to calculate – in advance – potential spatial impacts on the environment due to land use changes. It calculates the indicator values per postal zone for the whole of The Netherlands, only for those pre-defined biomass chain type – scenario combinations in which current crops will be replaced by (other) biomass crops. The framework tool reads the Miterra output values of the postal zones from file and selects the relevant zones to compute the impacts due to land use change. The Miterra model uses input data for its calculations that are available per postal zone, and its results cover whole postal zones, while the map operations in the framework tool are done in grid cells of 100x100m. Therefore the Miterra results must be considered as approximations (but this is valid for all results of the tool).

To run the current framework tool, the computer should have the Windows XP environment, the VB-program ME4_tool.exe with a pre-defined directory structure, ArcGIS version 9.3.4, ArcInfo workstation, and Excel version 2003.

4. Results regional biomass chain evaluation

4.1 Introduction

This Chapter gives the results of various case studies of five regional biomass chains (see Table 10). The results were generated with the framework and/or a selections of all of the available tools, models and approaches within the project. The straw case was used at an early stage of the project mainly to develop the methodology of the framework. In the second stage the pellet case was then used to verify the newly developed framework approach. The cases 1st generation bioethanol and 2nd generation bioethanol were the result of an extensive study of van der Hilst et al. (2010). Components of the integrated framework were either used (like the Miterra model) or developed (like the NPV methodology and the economic and environmental indicators) in these two case studies. Actually these two case studies generated the most comprehensive results within the regional biomass chain assessment. Within the fifth case only a description of the complex biorefinery value chain was given. No calculations were performed with the framework yet for the biorefinery case.

Table 10.
Five case studies of biomass supply chains.

No.	Name	Technology	Biomass type
1	Pellet case	Pelletizing residues followed by combustion to produce electricity and heat	Primary and secondary (woody) residues from natural areas
2	Straw case	Combustion of crop residues to produce electricity and heat	Agricultural residue: straw
3	1st generation bioethanol from sugar beet case	Fermentation	Sugar beet crop
4	2nd generation bioethanol from Miscanthus case	Hydrolysis and fermentation	Miscanthus crop
5	Biorefinery case	Biocascading	Sugar beet

4.2 Pellet case[10]

4.2.1 Introduction

Existing environmental standards and certification systems for production and logistics of biomass chains do not consider the spatial impacts of biomass production and conversion. A chain converting chipped wood from landscape elements plus industrial wood saw residues into pellets for combustion has been described and analysed. Primary details of the chain have been derived from a report (Meesters et al., 2008), while additional key figures were obtained from literature.

4.2.2 Results

A biomass chain is described annually converting 180,000 tons of wood and wood residues into pellets for combustion. The chain is to be situated in the east of The Netherlands. Local woody landscape elements (hedges, woody lanes, bushes, small forests, nature areas) and industries will each supply half of the required biomass (harvested wood and saw residues, respectively). Wood is harvested and chipped near the roadside, after which it is further transported. Wood chips are converted into pellets, which are transported to several combustion units (e.g. electricity generating units, utilities, etc.) (Figure 16). For the sake of the analysis, one single combustion unit (64 MW) is included in the analysis.

Figure 16.
Schematic layout of the pellet chain.

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[10] The chain presented here is partially based on Meesters et al. (2008) - Duurzaamheidsanalyse pellet keten.

Data were collected to calculate energy requirements for chipping, loading, transport, unloading, pelletizing and further distribution. These were used to calculate energy and GHG balances as well as economic returns of the pelletizing chain. Results suggest positive economic and energetic returns, while over 160 thousand tons of CO_2-eq could be avoided (Table 11). Data plus outcomes then were fed into the project framework (see Chapter 3) in a standard format, allowing easy and automized data analysis.

Table 11.
Main chain characteristics and results.

Phase	Inputs	Outputs	Remark
Wood collection and chipping	Harvested wood (95 ton/y)	Chips	In the field. Transport of chips to pellet factory
Wood collection	Industrial saw residues (95 ton/y)	Chips	Near factory. Transport of chips to pellet factory
Pelletizing	Chips	Pellets	
Combustion	Pellets (95 ton/y)	Heat, power	1700 GJ (550 Gjel and 1200 GJh)
Economic performance	12 mln € (costs)	31 mln € (revenues)	19 mln € (result)
GHG balance	4,000 ton CO_2-eq (emitted)	165,000 ton CO_2-eq (avoided)	161,000 ton CO_2-eq (net avoided)

Additionally, chain characteristics and outcomes were used to test applicability of bioenergy chains for sustainability certification against the Dutch NTA 8080 standard (Poppens, 2011). The NTA 8080 describes the minimum requirements that organizations need to comply with, in the production, conversion, trading, transport and/or use of biomass for energy purposes. This additional analysis has revealed to what extent the project's sustainability framework matches up with the Dutch NTA 8080 standard, in terms of coverage of sustainability criteria and accuracy of measures. For all pellet chain components, both compliance and incompliance with NTA 8080 were discussed, as well as the level of coverage by the project's sustainability framework. Besides validating the project sustainability framework, the results reveal whether, and how, a pellet company could successfully acquire a NTA 8080 certificate, as testimony to compliance with this standard's complete set of stringent sustainability criteria.

The NTA 8080 analysis results can shed light on the potential for biomass-to-energy production in The Netherlands. When sustainability of all biomass related chain operations can be demonstrated against the formal sustainability requirements of the NTA 8080 standard, landscape elements throughout The Netherlands may regain their importance for rural economies. This may provide an important mechanism for long-term protection of valuable landscapes, and at the same time contribute to fighting global climate change.

Table 12 provides a summary, listing the NTA 8080 coverage of each tool, its current usability and limitations in biomass chain assessments and its potential for improvements.

Table 12.
ME4 Sustainability Framework tools.

Tool	NTA coverage	Current applicability	Limitations	Potential (?)
MITERRA model	o Environment (soil only) o GHG balance	o (Soil) carbon stock o GHG emissions	o No wood chains o No surface and ground water o No air	o Interlink parameters for environment, biodiversity and economics
Manual	o Stakeholder consultations	o Methodology for improved stakeholder involvement	o Not tested in real case	o Include participation by stakeholders covering all NTA 8080 components
Economic tool	o Prosperity	o Profitability assessment of willow harvesting	o No wood from nature/ landscape management	o Include non-cultivated wood and non-wood landscape biomass o Include iLUC avoidance costs

The ME4 project framework tool covers (parts of) environment, greenhouse gas balance, stakeholder consultations and prosperity. The remainder of NTA 8080 sustainability components are not covered, or only indirectly. Non-coverage of documentation and legality requirements is understandable, given that the tools were not designed for assessment of specific organizations.

Indirectly, additional NTA 8080 requirements may be covered by the stakeholder consultation methodology described in the manual. Provided it aims to include stakeholders that sufficiently cover the NTA 8080 scope, sustainability could significantly improve through their input. However, the stakeholder methodology needs testing first, as well as alignment with NTA 8080.

ME4 project partners may want to look for improved NTA 8080 coverage by their sustainability framework tools. Perhaps the MITERRA model could be developed to include non-agricultural biomass and indicators for biodiversity, surface and ground water and air.

The economic tool could perhaps be developed to calculate the costs of avoiding indirect land use changes (iLUC) for a variety of agricultural and non-agricultural biomass types. Presumably, this could be measured against performance on a variety of soil types, with different levels of competitiveness against alternative uses (food and non-food). Such tool may be instrumental in establishing the niche for different biomass crops, taking into account both direct and indirect effects. Regarding the manual, it is recommended to test the stakeholder consultation methodology in the field and align it with the NTA 8080.

4.2.3 Conclusion

Perspectives and impacts of bioenergy production in The Netherlands have been assessed for a fictitious wood pellet production chain in the east of the country. Data for this chain were retrieved from a business plan, and evaluated for sustainability performance. Using the framework for bioenergy production analysis developed in the project, an assessment was made of GHG savings by combustion of the wood pellets.

4.3 Straw case[11]

The spatial fragmentation of different biomass sources in one or more regions makes design and assessment of sustainable biomass delivery chains rather complicated. In an early stage of the project a GIS-BIOLOCO tool was developed that supports the design and facilitates a sustainability assessment of biomass delivery chains at a regional level, in terms of the regional availability of biomass resources, costs, logistics and spatial implications. The tool consists of the BIOLOCO model (Diekema et al., 2005) which optimizes the biomass chain to a set of pre-defined economic and Green House Gas (GHG) targets. The model is linked to a GIS basis, to take account of the detailed spatial pattern (dispersion and concentration) of biomass resources. The combination of BIOLOCO with GIS makes it possible to (i) compute more accurately the expected supply of biomass in a certain region, (ii) compute more accurately the transportation distances, related costs and GHG emissions, and (iii) to assess the spatial impacts of the feedstock requirements of different chain designs on land use, environment, landscape and biodiversity.

In this early stage of development of the framework a case study was assessed using the GIS-BIOLOCO application. This was a straw-based bioenergy chain based on current land use in The Netherlands. The bioenergy chain consisted of two possible locations for a conversion unit (indicated as star in Figure 17-a) requiring 30.000 ton dry matter (DM) to produce 110.000 GJ electricity. The optimization target was to maximize the profit margin of the conversion unit by choosing the best location. The biomass supply map was based on the straw production of the three most dominant cereals in 2006 (Figure 17-b). At the moment straw is partly harvested and sold by farmers to e.g. cattle or horse owners. It was assumed that only a part of this (only 25%) would be available for bioenergy production. Based on the straw supply map, GIS-BIOLOCO optimized the chain for the profit margin and generated a straw withdrawal pattern as presented in Figure 17-c. Withdrawal patterns are based on supply per grid cell, distance and feedstock price.

The withdrawal pattern of the straw to electricity chain is fairly condensed and located in the direct vicinity of one conversion unit that was chosen by the optimization. In competition with this conversion unit, the second conversion unit was not economically viable.

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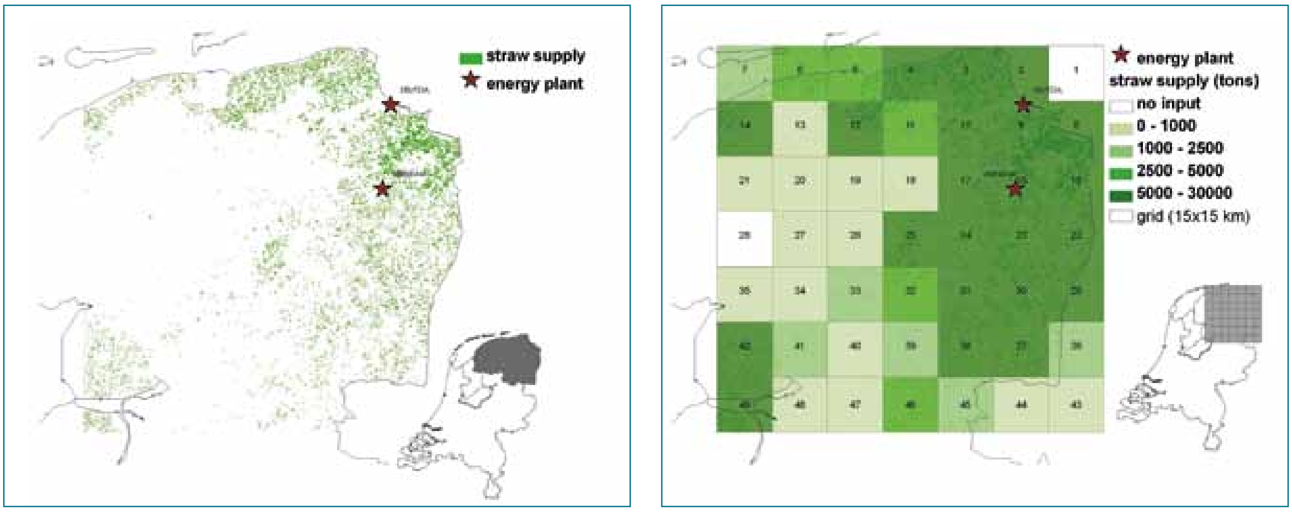
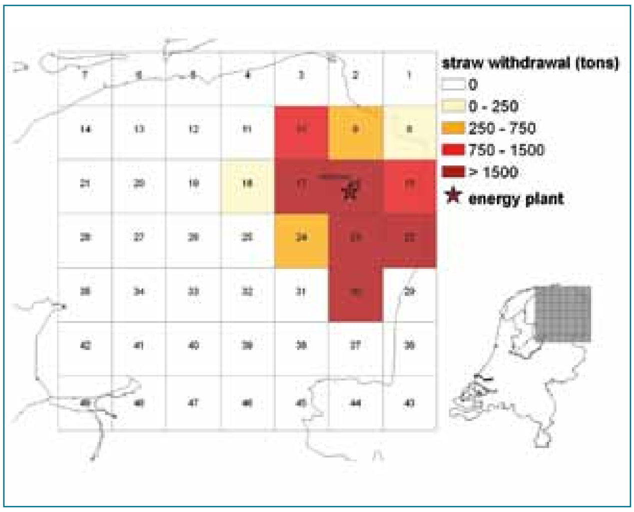
[11] Based on Geijzendorffer et al. (2008) - Application of GIS-BIOLOCO for design and assessment of biomass delivery chains.



(a)

(b)



(c)

Figure 17.
(a) Straw supply per field in the North of The Netherlands, (b) Map of potential straw supply per grid cell, (c) Straw withdrawal pattern by conversion unit in Veendam, The Netherlands.

4.4 1st generation bioethanol from sugar beet[12]

The results show that sugar beet for ethanol cannot compete with current cropping systems in terms of return per hectare. In addition, the minimum cost of feedstock production of 9.7 €/GJ (see Figure 18) cannot complete with other domestically produced types of biomass (for example Miscanthus) or with biomass imported from abroad. The cost of bioethanol from sugar beet (27 €/GJ) is not competitive with petrol (12.34 €/GJ) production under current circumstances.
The assessment of environmental performance of bioenergy crops shows that there are large spatial variations in environmental impacts (see Figure 19). Land use change (LUC) to sugar beet generally causes more negative environmental impacts than LUC to Miscanthus. This is especially true for the (wet) pasture areas. The GHG balance is dominated by the change in soil organic carbon (SOC) especially when pastures are converted to sugar beet production. In addition, first generation bioethanol requires considerable energy inputs for steam production which cause significant GHG emissions. A shift to sugar beet production generally increases the risk of erosion, especially on sandy soil and areas currently in use as pastures. The water deficits during summer will generally

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[12] Based on van der Hilst et al. (2010). Potential, spatial distribution and economic performance of regional biomass chains: The North of The Netherlands as example.

decrease when pasture land is converted to sugar beet and will increase only minimal when arable land is used for sugar beet cultivation. The water use efficiency (WUE) of ethanol production from sugar beet is relatively high due to the relative high yields. Due to the relative high fertilizer requirements the NO_3 concentration and P surplus will increase when arable land is converted o sugar beet cultivation. Because of the current high application levels of manure on pastures, the NO_3 concentration and P surplus will decrease when grasslands are changed to sugar beet. In most areas the risk on biodiversity will increase when land use is changed to sugar beet cultivation. This is especially true meadow bird rich wet pasture areas. The integrated results show several trade-offs between the environmental impacts but the overall environmental impact is negative when current land use is converted to sugar beet.

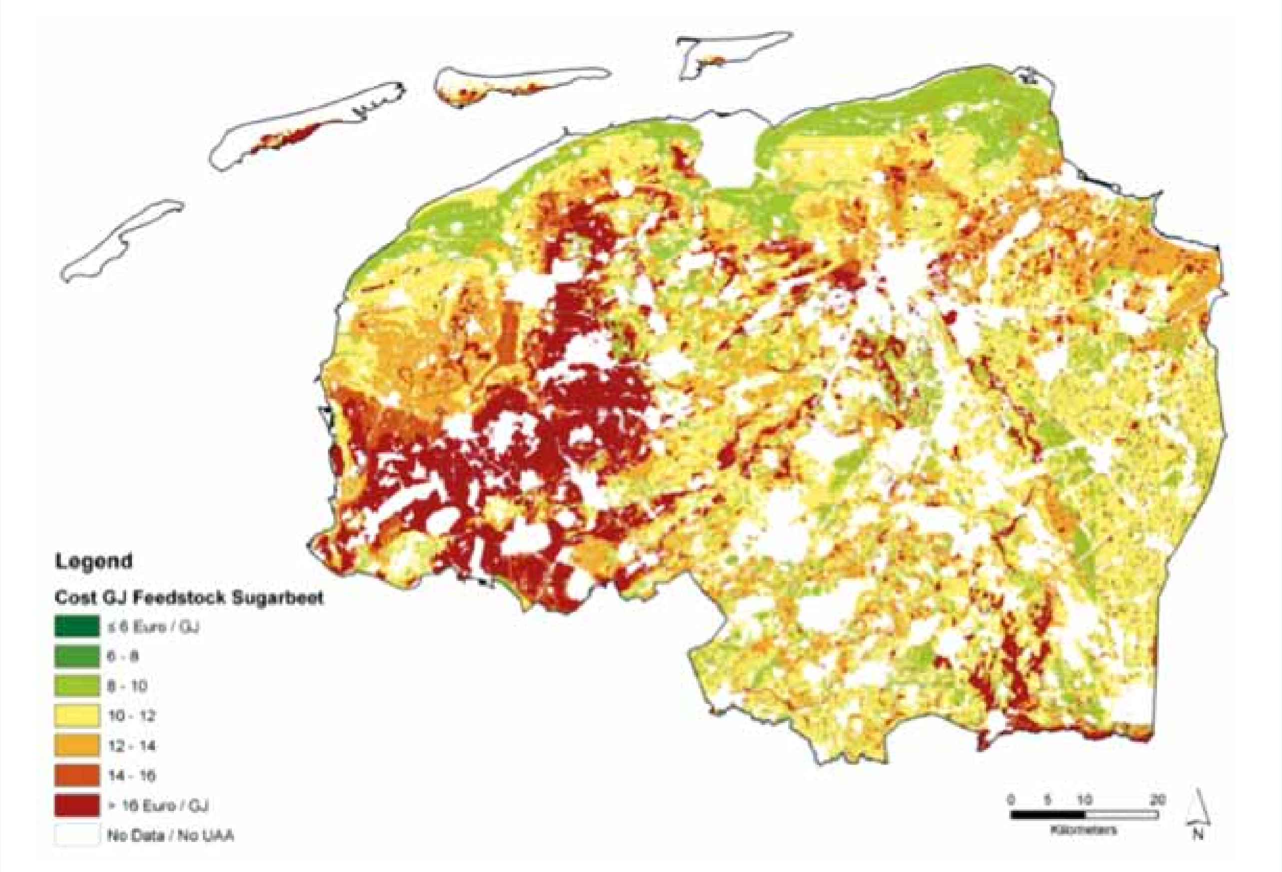

Figure 18.
Cost of the feedstock production Sugar beet (euro/GJ).

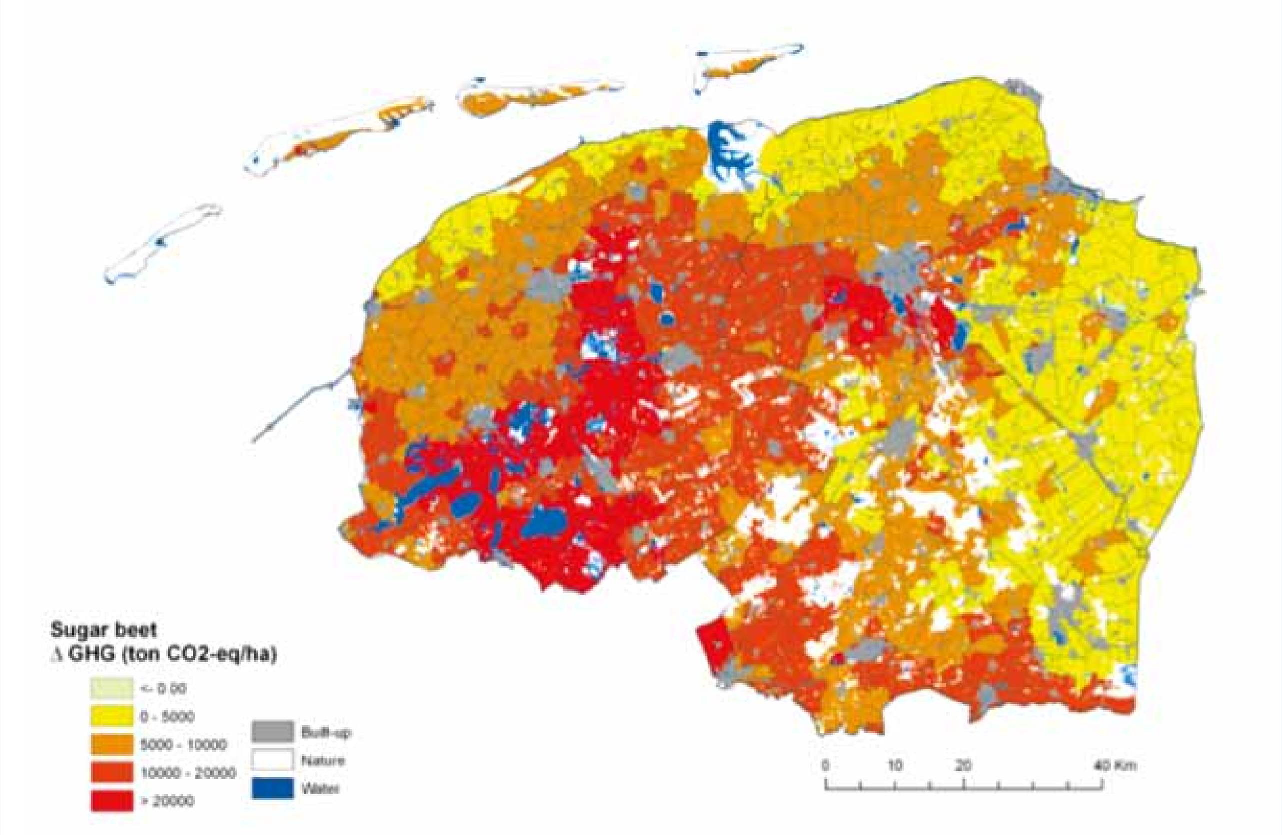

Figure 19.
Difference Green House Gas of the feedstock production Sugar beet (kg CO_2-eq/ha).

4.5 2nd generation bioethanol from Miscanthus[13]

The results show that the cultivation of Miscanthus is not competitive with current cropping systems on soils classed as "suitable". On less suitable soils, the return on intensively managed crops is low and perennial crops achieve better NPVs than common rotations. The minimum feedstock production costs are 5.4 €/GJ for Miscanthus (see Figure 20). Ethanol from Miscanthus (24 €/GJ) might become a less costly option than ethanol from sugar beet (27 €/GJ) but the cost of bioethanol production from domestically cultivated crops is not competitive with petrol (12.34€/GJ) production under current circumstances.

There are large spatial variations in environmental impacts of Miscanthus (see Figure 21). For most impacts Miscanthus could have both positive and negative effects. The GHG balance is dominated by the change in soil organic carbon (SOC). The SOC generally increases when current land use types are converted to Miscanthus cultivation, except for areas on organic soils. In addition, second generation bioethanol requires a considerable amount of chemical inputs which cause significant GHG emissions. When arable land is converted to Miscanthus, erosion risk is significantly reduced. Although it is assumed that grass is renewed every 10 years and Miscanthus every 20 years, risk on erosion increases when pastures are converted to Miscanthus. In general, when land is converted to Miscanthus water deficits during summer will increase in the whole region. As evapotranspiration of rotation crops is lower than of pastures, the change from arable crops to Miscanthus will causes the biggest differences in water deficits. Although, C4-crops generally have a higher WUE than C3-

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[13] Based on van der Hilst et al. (2010). Potential, spatial distribution and economic performance of regional biomass chains: The North of The Netherlands as example.

crops, Miscanthus is less water use efficient than sugar beet because in the region of assessment the typical benefits of a C4-pathway is limited due to sunlight hours. Because of the low fertilizer requirements and the high retention capacity of Miscanthus, the P surplus and NO_3 concentration will be reduced when current land use is converted to Miscanthus cultivation. The spatially combined results of the environmental impacts illustrate that there are several trade-offs between environmental impacts. There is no area where only positive or only negative impacts occur.

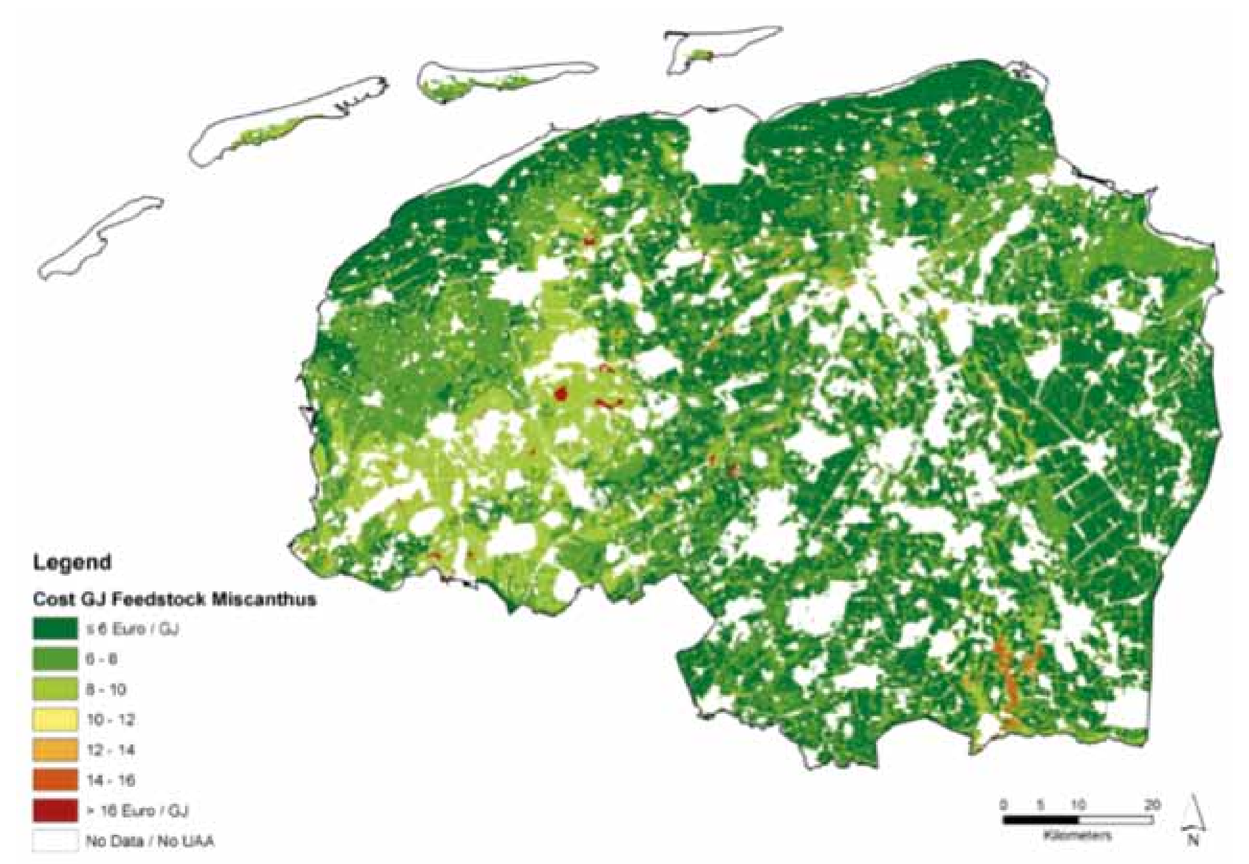

Figure 20.
Cost of the feedstock production Miscanthus (euro/GJ).

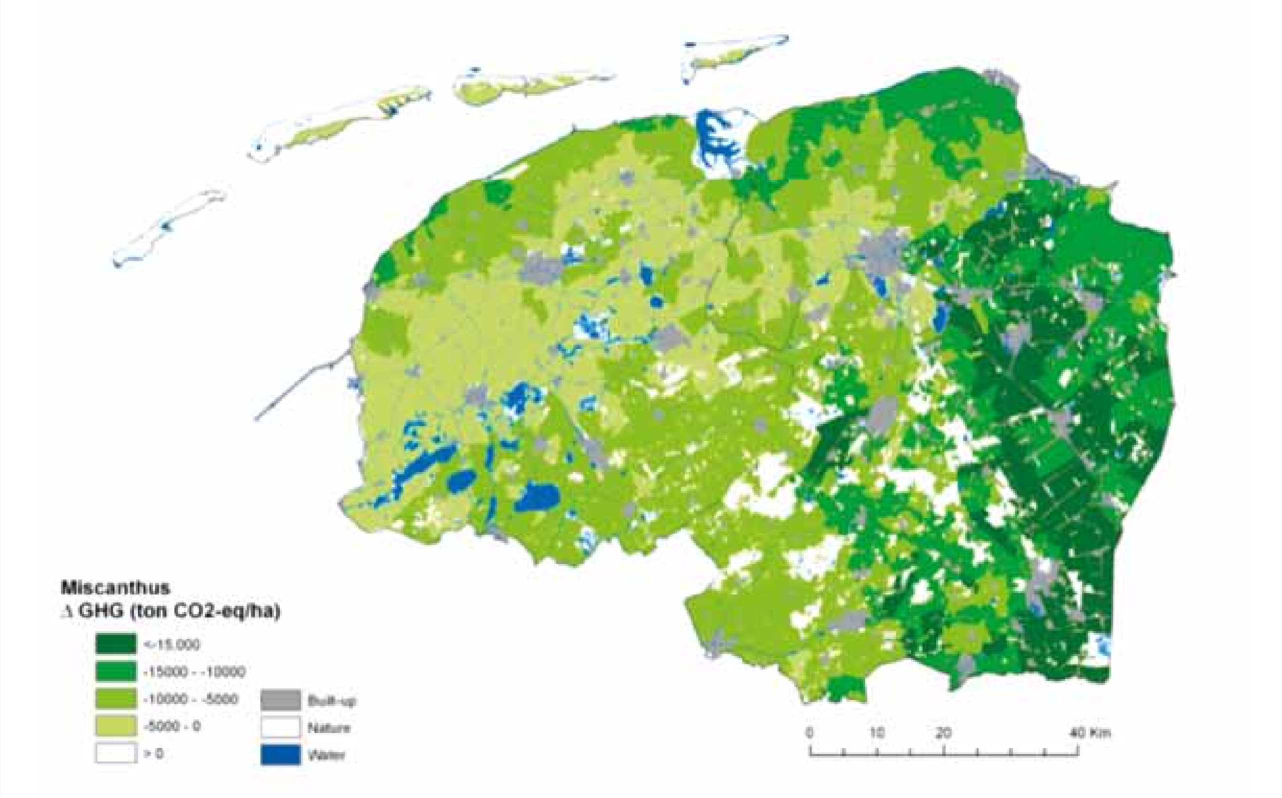

Figure 21.
Difference Green House Gas of the feedstock production Miscanthus (kg CO_2-eq/ha).

4.6 Biorefinery case

The Biorefinery case is an example of much more complex biomass chains, since more than one product is manufactured from an agricultural crop or residue. We defined a case in which not only the beet was used but also the leaf of the crop. This process manufactures crystalline sugar, ethanol, biogas from the beet and also protein, fibres and biogas from the leaves.

Such processes will be much more economical as compared with single product chains in which the product is used for it caloric value only. Also if the processes are well developed they will have a better contribution to several impacts as we have studied as e.g. the reduction of GHG in the whole chain.

Such whole crop biorefinery systems can also benefit from the combination of different raw materials to increase the economic viability which is required when the biobased economy will mature and more and more competition between players will develop.

So far the framework tool has not implemented these more complex chains yet.

5. Dialogue on sustainability of bioenergy

5.1 Background[14]

The social controversy on energy from biomass points to a complex issue, which relates to not only a variety of norms and values but also to different perspectives and expectations as regards the facts. In the current debate parties tend to talk to each other instead of with one another. They are strongly attached to their own 'right'. Images have been created that are difficult to change. It is generally expected from science to create an unambiguous image of reality, but this is far from the case. As to clarify and structure the debate on biomass to energy, thereby articulating and confronting conflicting positions, a dialogue process is an appropriate approach.

Therefore, in 2007 - 2008, the Institute for Environmental Studies (VU University of Amsterdam) and the Copernicus Institute (Utrecht University) organized a stakeholder dialogue in the context of the project that explored options for production and use of energy from biomass for The Netherlands. This work is briefly called: the Biomass Dialogue. Questions to be addressed were:

- Where are opportunities?
- Where are risks and (how) can these be mitigated?
- Are biomass initiatives worthwhile given the expected environmental benefits?
- Is it possible to reach shared conclusions on such a topic that keeps stakeholders so divided?
- What can we learn from the Biomass Dialogue, especially parties considering to take biomass related initiatives?

5.2 Process approach

The process approach was based on lessons learnt on previous biomass-related dialogue projects, especially the project Costa Due, aimed at developing and implementing biomass to energy activities in Northern Groningen (Eemsmond).[15] The main lessons from this project were that the usefulness of insights on new opportunities for energy from biomass increases when there is a clear structure. This on the one hand allows to discuss concrete ideas and proposals and on the other hand urges participants to take a future oriented point of view as to allow for out-of-the-box thinking. The Costa Due network also provided guidance in the recruitment of dialogue participants for the Biomass Dialogue.

The Biomass Dialogue was designed according to the three main stages in the back-casting methodology. Back-casting enables to explore ambitious visions and the trajectories to be taken, reasoning backwards from an end state 'as if it were already obtained'. Back-casting is appealing as it encourages 'out of the box thinking', thereby avoiding the conservatism inherent in scenario building approaches known as 'forecasting'. Critical is the identification of barriers and opportunities along the way. The Biomass Dialogue was divided into three one day workshops, concentrating on (i) assessing present-day energy from biomass applications, which resulted in identifying shortcomings in today's practice and main criteria for improvement, (ii) assessing possible future options, resulting in the identification of constitutive elements for a sustainable energy system with a major contribution from biomass-based energy, and (iii) reasoning backwards from the sustainable future

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[14] Chapter based on Hisschemöller et al. (2009) - A dialogue on the sustainability of energy from biomass; Visions, chains and perspectives.

[15] Concrete Steps toward a Sustainable Eemsmond region, initiated and coordinated by Groningen province. See for a detailed description and analysis of this project *Fransen (forthcoming)*.

to the less sustainable present, identifying barriers and opportunities taken along the way. This resulted in the identification of some key institutional issues for The Netherlands.

Important lessons are related to dialogue process. First of all, both participants and the project team itself found that openness with respect to different perspectives must prevail in any process. Preceding the actual Biomass Dialogue we articulated and analysed the different perspectives that underlie the views of a broad variety of Dutch stakeholders, using Q-methodology. This resulted in the identification of six perspectives on biomass-to-energy (Cuppen et al., 2010). During the dialogue, all options presented were discussed and assessed from the angle of these perspectives. This happened in homogeneous subgroups, bringing together stakeholders arguing from a similar perspective, as well as in heterogeneous groups, where persons argued from different perspectives. A fair process, which seriously considers these perspectives, is a prerequisite for mutual recognition and learning. Following the dialogue, Cuppen (2009) evaluated learning throughout the dialogue by a repeated Q-interview with respondents from the dialogue group and a control group of respondents who had not taken part in the dialogue. Analysis showed that dialogue participants had indeed learned from one another. Recognition of different viewpoints, including more marginal ones, had increased among dialogue participants and decreased among non-participants. Some participants preferred a different perspective after the dialogue as compared to before.

A second lesson as regards the dialogue process is that a focus on specific options and topics rather than general values encourages an exchange of views and information. The dialogue discussed specific biomass chains. Stakeholders immediately involved gave presentations. The different options were also presented in writing and visualized through cartoons. This stimulated a lively discussion and contributed to information exchange during the dialogue.
Box 1 gives an overview of specific options presented and discussed.

Box 1.
Biomass chains presented in workshop 1 and 2 (Breukers, Hisschemöller, Cuppen & Suurs, forthcoming).

Biomass chains presented in workshop 1:
1. A small biomass installation using municipal trimmings,
2. A demo-plant for the production of biodiesel from waste-fats (from restaurants and snack bars)
3. A manure co-fermentation plant on a pig farm
4. Production of Pure Plant Oil (PPO) from rape seed and a service to adapt diesel engines for PPO use
5. A large global-scale bio-ethanol chain for the blending with petrol

Biomass chains presented in workshop 2:
1. Algae: production of biodiesel, heat and electricity
2. Biofuels through large scale Fischer-Tropsch synthesis
3. Innovative ethanol-chains based on sugar beets
4. Small-scale pyrolysis of biomass in developing countries, combined with carbon capture / underground storage, food production and small scale electricity production
5. Pressed oil for production of heat, cold, food and feed
6. Recycling paper? (this presentation was mainly intended to clarify the dilemma's when choosing for CO_2 or energy efficiency in situations where they cannot be accomplished both)

Recommendation

An energy-from-biomass related initiative can benefit from involving stakeholders with divergent perspectives from the beginning. It will be tempting to exclude parties who are expected to oppose, but this may backfire. Also the most critical perspectives might be involved. At the same time, the initiative may ask an open and constructive attitude on the side of all involved (learning through action). The Biomass Dialogue shows that this is possible, if the diversity of perspectives is reassured throughout the process.

5.3 Sustainability of biomass

The dialogue shows convergence with respect to sustainability criteria. The main sustainability themes previously developed for Dutch government by the Cramer Commission meet with support. Yet, in addition to these criteria that primarily address issues of substance, the dialogue points to the relevance of one procedural criterion as well, i.e. transparency and verifiability of chains by those immediately involved, including interested (potential) customers. This is especially relevant with respect to concerns on the impacts for developing countries. As to guarantee transparency and verifiability for stakeholders in all parts of the chain (trade, import, distribution companies and end users) local NGOs must play their part. Modern communication options can be used for facilitating ‘on site inspections’ and communication with local producers. Although the requirement of chain transparency is not inconsistent with policy proposals for biomass certification, both options do not necessarily coincide. As yet, Dutch policies concerning certified biomass allow for secrecy with respect to (parts) of the chain, e.g. the origins of imported biomass. Some dialogue participants argue that systems providing full access to information will be cheaper and more effective in the end than certification. According to these participants, certification schemes will result into bureaucratic hustle, which makes them expensive and hence, provide a mechanism to exclude small players from entering the market. In contrast, big players will be likely to resist transparency for reasons of company security. Hence, mechanisms that focus on open information and communication will be easier to implement in small-scale projects than in large-scale projects.

Recommendation

Dutch government must, parallel or complementary to current certification schemes, develop and test systems for open information exchange among stakeholders involved in bio energy projects. Initiators of these projects must themselves take initiatives in this respect.

Another issue discussed is the potential discrepancy between EU sustainability criteria and national policies that want to be more stringent in this respect. Basically, EU sustainability criteria will prevail over national policies. When there is the political will at national level to move forward, be it under strict conditions, then national government can consider to use and further develop the concept of public procurement. If public procurement is employed in a way as to enable the full range of parties on the supply side, both large and small players on an equal footing, this policy instrument can enhance the adoption of innovations in the field of energy from biomass.

Recommendation

Public procurement must be employed as to learn with respect to the feasibility of biomass options for the energy transition. National government will form a coalition with local governments and, where possible, private parties on the demand side. This coalition will publish a tender asking for sustainable transport with specifications on sustainability criteria, ranging from vehicle efficiency to sustainable fuels. In their tender, the ‘demand coalition’ can, if they want to promote innovation, ask for diversity as to include different innovative options in their package. This will trigger the formation of (competing) consortia on the supply side, including car manufacturers and companies offering clean fuels. It is critical that public procurement will relate to the entire chain instead of, which is current practice, to compartmentalize the chain by separating between vehicles and fuels.

5.4 Conclusion

In conclusion, the Biomass Dialogue has offered an understanding of the divide with respect to sustainability of biomass to energy as well as a possible way-out. Part of the dialogue participants have stressed that we will have to accept that, in a learning by doing process, things may go wrong. The current Dutch 'culture' with respect to energy from biomass is featured by postponing action under the assumption that 'next generation' options will be really sustainable. If this remains the dominant attitude, we may never face a transition or we will be forced into it by global developments. For another part of dialogue participants, risk aversion is critical. The dialogue has highlighted a possible compromise between these two perspectives, as comes out of the recommendations. A step-by-step approach as proposed in the recommendations may reconcile the divergent perspectives, focusing on learning by doing through small-scale projects so that risks can be signalled at an early stage.

6. Conclusions & recommendations

6.1 General

The ME4 project outcomes suggest that science can support the development of sustainable bioenergy production chains in The Netherlands. The support can cover disciplinary and interdisciplinary analyses on biomass availability and logistics, on policy and economic analysis, on sustainability performance of production chains as well as on chain development integrating input from different types of stakeholders. The project has involved researchers from a considerable number of research and technology development institutions, effectively integrating research backgrounds including agronomy, technology, economy, as well as policy and social sciences.

While focussing on the perspectives of actual, potential and perspective bioenergy development, the project defined, described and analysed energy, economic and ecologic features of biomass chain development for The Netherlands. An integrated analytical framework was developed and implemented, features of which have been reported. Practical aspects of both biomass chain development and analysis have been tested by defining and analysing bioenergy chains focussing on different basic feedstocks and conversion routes for The Netherlands: electricity and heat production from wood pellets or straw, biofuel production from first or second generation crops as well as a more advanced biorefinery chain based on crops like sugar beet.

Integrating researchers from a wide range of disciplinary backgrounds, distributed over a number of universities and other institution, project member input has been organised in different Work Packages (WP´s). Four work packages covered the specific elements of the project work, WP1 mainly focussing on economic biomass availability and logistics management issues, WP2 on integrated chain production and sustainability impact analysis, WP3 on policy analysis and WP4 on stakeholder interaction processes and participation involvement. Scientific relevance, technology development and general analytical integration have been enhanced by involvement of two PhD students.

The ensemble of work done in the respective work packages plus integral PhD research has been devoted to the issue of sustainable bioenergy production chain development for The Netherlands and the EU. Specific outcomes have been reported in previous chapters and a number of specific conclusions are presented in the next sections.

6.2 Biomass in The Netherlands and EU present and future situation

Factors were identified and evaluated that are crucial for successful bioenergy production chain development. These include (Langeveld et al., 2010b):

- successful selection of a suitable location and, obtaining necessary licenses for operating bioenergy production technologies;
- organizing generic support for bioenergy initiatives at a wider scope;
- availability of sufficient reliable (information on) proven technology;
- sharing of independent (scientific) data on issues like odour, noise, and emissions from installations between stakeholders involved in the chain development.

For the chain design process the following issues need to be solved (Langeveld et al., 2010a & 2010b):

- rules for the localization of installations (digesters), and directions for (odour, noise, emissions) nuisance;
- dissemination of production and sales data (non-transparent and underdeveloped markets);
- testing and spreading of new technologies (producers, installers, entrepreneurs, public);
- include bioenergy production as policy theme.

In this study two contrasting scenarios for the integrated analysis of biomass delivery chains were selected out of the four original ‘strategic orientation’ Eururalis scenarios, Global Economy (GE) and Regional Communities (RC), and combined with three levels of low, base, and high policy intervention. The objective was to outline extreme conditions, and to study what happens as a result of those conditions. The Global Economy (GE) scenario has as its mission statement, that market-based solutions are the most efficient way to achieve strong economic growth and optimise demand and supply of goods, services and environmental quality. The Regional Communities (RC) scenario has as its mission statement that self-reliance, environmental stewardship and equity are the keys to sustainable development, and local communities being the cornerstones of society.

The Dutch biomass demand and supply in 2010-2030 was studied. The analysis tried to identify the main biomass sources under different scenario situations. An estimation was provided of the spatial distribution of the main biomass sources contributing to the final 2020 renewable energy target. The GE and RC Scenarios were used to further translate the 2020-2030 energy demand into a renewable energy and bioenergy demand. The Dutch biomass streams to be used for the production of biofuels are: used oil, grass, residues from food and stimulants industry, potato and beet crops, rapeseed, salt-tolerant grasses and other crops (cultivated on the Dutch coastal areas), and seaweed. The Dutch biomass streams to be used for the production of chemicals are: grass, residues of rapeseed and wheat processing, manure (urea for fertilizers, proteins for chemicals), potato and beet crops (N- or O-functionalized chemicals), salt-tolerant grasses and other crops (cultivated on the Dutch coastal areas), and seaweed. The assumed potentials for both the GE and RC Scenarios are quite high, and can fulfil a considerable fraction of the biomass demand in each sector of the both scenarios. However, still additional biomass needs to be imported in order to match the demand for biomass in both scenarios. The total biomass potential map of The Netherlands shows the potential for the Global Economy scenario and the Regional Communities scenario, which has by far the largest potential. According to the map the best regions in The Netherlands to set up biomass feedstock chains are concentrated in the Randstad area, most parts of Brabant, the centre of the country in Flevoland, and the North of Gelderland.

The biomass resource potential and related costs in the EU-27 and the Ukraine have been determined in cooperation with the REFUEL project (de Wit & Faay, 2010). Results indicate that the total available land for bioenergy crop production – following a 'food first' paradigm – could amount to 900,000 km^2 by 2030. Feedstock supply of dedicated bioenergy crop estimates varies between 1.7 and 12.8 EJ y^{-1}. In addition, agricultural residues and forestry residues can potentially add to this 3.1–3.9 EJ y^{-1} and 1.4–5.4 EJ y^{-1} respectively. First generation feedstock supply is available at production costs of 5–15 € GJ^{-1} compared to 1.5–4.5 € GJ^{-1} for second generation feedstocks. Costs for agricultural residues are 1–7 € GJ^{-1} and forestry residues 2–4 € GJ^{-1}.

Looking at the developments in European agriculture, it was studied how fast and to what maximum yield improvements can be realized in Europe in the coming decades and what the opportunities and relations are to biomass production. At the extremes the European bioenergy potential, assuming average bioenergy crop yields, can amount to 5.1–9.3 EJ y^{-1}. High yielding lignocellulosic crops could double this potential. It is concluded that the potential to free-up agricultural lands for the production of bioenergy crops in Europe is considerable. The degree to and the pace at which yields develop will determine how much of the potential is opened up. Agricultural policy and technological development are key to open up the potential.

A key aspect in modelling the (future) competition between biofuels is the way in which production cost developments are computed. An analysis was executed with the European biofuel model BioTrans, which computes the least cost biofuel route. The model meets an increasing demand, reaching a 25% share of biofuels of the overall European transport fuel demand by 2030.

The cumulative greenhouse gas emissions (GHG) of N_2O, net soil organic carbon fluxes and abated emissions from replacing fossil transport fuels by biofuels are evaluated for nine land use variants with MITERRA-Europe. It is found that it is possible to combine large-scale biomass production, sustain current food production levels without (in)direct land use changes and accomplish significant net environmental benefits in European agriculture. Results suggest that research or policy efforts aimed at further increase of productivity raise the output from existing European cropland while at the same able to reduce or mitigate emissions.

6.3 Framework tool for integrated spatial design and assessment of regional biomass chains

A framework tool for the integrated spatial design and assessment of regional biomass delivery chains was designed and built as described in the flowchart in Figure 6. It contains four modules:

- pre-defined data;
- generation of national biomass potential maps;
- chain specification;
- impact assessments.

The framework tool can be used to support practical processes with stakeholders and researchers having the intention to practically implement biomass delivery chains. The development of the tool in this project has confirmed that a lot of practical knowledge, existing models, and data can be captured in a framework enabling an integrated view of both spatial consequences, environmental and economic performance of new biomass delivery chains designed in an iterative process with stakeholders and researchers. The frequent application of the framework tool in the design and assessment of a new biomass delivery chain can lead to a further improvement and wider applicability of the framework.

The complexity of the biomass chains integrated in the present framework is still limited. Further application of the framework tool will increase the complexity of the biomass chains the framework can handle.

The development of the framework tool also confirmed that not all knowledge and data can be captured in a formalised framework environment. This especially applies to social criteria. This however, is not necessary as design and practical implementation of biomass delivery chains needs the involvement of many stakeholders in a wider communication process. The tool can be supportive in this interaction process, especially through provision of quick and better understanding of the spatial, environmental and economic consequences of a large range of choices that need to be made to come to a final chain designing and practical implementation in a region.

6.4 Regional biomass chains evaluation

Five regional biomass chains have been pre-defined within the framework and were used as case studies.

Perspectives and impacts of bioenergy production in the Netherlands have been assessed for a fictitious wood pellet production chain in the east of the country. Data for this chain were retrieved from a business plan, and evaluated for sustainability performance. Using the framework for bioenergy production analysis developed in the project, an assessment was made of GHG savings by combustion of the wood pellets. The ME4 project framework tool covers (parts of) environment, greenhouse gas balance, stakeholder consultations and prosperity. The remainder of NTA 8080 sustainability components are not covered, or only indirectly. Non-coverage of documentation and legality requirements is understandable, given that the tools were not designed for assessment of specific organizations.

A GIS-BIOLOCO tool was developed that supports the design and facilitates a sustainability assessment of biomass delivery chains at a regional level, in terms of the regional availability of biomass resources, costs, logistics and spatial implications. A straw-based bioenergy chain based on current land use in The Netherlands was assessed using the GIS-BIOLOCO application. Based on the straw supply map, GIS-BIOLOCO optimized the chain for the profit margin and generated a straw withdrawal pattern.

Two biofuel cases were compared: 1st generation bioethanol from sugar beet with 2nd generation bioethanol from Miscanthus. The results show that sugar beet for ethanol cannot compete with current cropping systems in terms of return per hectare. In addition, the minimum cost of feedstock production of 9.7 €/GJ cannot complete with other domestically produced types of biomass (for example Miscanthus) or with biomass imported from abroad. The results also show that the cultivation of Miscanthus is not competitive with current cropping systems on soils classed as "suitable". On less suitable soils, the return on intensively managed crops is low and perennial crops achieve better NPVs than common rotations. The minimum feedstock production costs are 5.4 €/GJ for Miscanthus.

The main socio-economic impacts of the biofuel cases are (Hilst et al., 2010):

- on very suitable soil cash crops are more profitable than bioenergy crops;
- on low suitable soil the production costs of biomass crops are very high;
- medium soils are the best locations for growing Miscanthus;
- feedstock production costs are higher for sugar beet than for Miscanthus and both are more costly than feedstock imported from abroad;
- domestically produced ethanol from biomass is not competitive with petrol prices (yet).

The main environmental impacts of the biofuel cases are (Hilst et al., 2011):

- valuable methods have been found to assess the spatial variation of potential environmental impacts of bioenergy production spatially explicitly;
- the case study provides knowledge about preferable areas for bioenergy production and 'no-go' areas;
- there are trade-offs between the various environmental impacts: there are no areas where a shift towards bioenergy crop production results in only positive environmental impacts;
- conversion of arable land to Miscanthus generally gives positive environmental effects;
- conversion of pasture land to sugar beet generally gives severe negative environmental impacts.

The Biorefinery case is an example of much more complex biomass chains, since more than one product is manufactured from an agricultural crop or residue. We defined a case in which not only the sugar beet was used but also the leaf of the crop. So far the framework tool has not implemented these more complex chains yet.

6.5 Dialogue on sustainability of bioenergy

The Biomass Dialogue has offered an understanding of the divide with respect to sustainability of biomass to energy as well as a possible way-out. Part of the dialogue participants have stressed that we will have to accept that, in a learning by doing process, things may go wrong. The current Dutch 'culture' with respect to energy from biomass is featured by postponing action under the assumption that 'next generation' options will be really sustainable. If this remains the dominant attitude, we may never face a transition or we will be forced into it by global developments. For another part of dialogue participants, risk aversion is critical. The dialogue has highlighted a possible compromise between these two perspectives, as comes out of the recommendations. A step-by-step approach as proposed in the recommendations may reconcile the divergent perspectives, focusing on learning by doing through small-scale projects so that risks can be signalled at an early stage.

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Climate changes Spatial Planning

Climate change is one of the major environmental issues of this century. The Netherlands are expected to face climate change impacts on all land- and water related sectors. Therefore water management and spatial planning have to take climate change into account. The research programme 'Climate changes Spatial Planning', that ran from 2004 to 2011, aimed to create applied knowledge to support society to take the right decisions and measures to reduce the adverse impacts of climate change. It focused on enhancing joint learning between scientists and practitioners in the fields of spatial planning, nature, agriculture, and water- and flood risk management. Under the programme five themes were developed: climate scenarios; mitigation; adaptation; integration and communication. Of all scientific research projects synthesis reports were produced. This report is part of the Mitigation series.

Mitigation

The primary causes for rising concentration of greenhouse gases (GHG) in the atmosphere are fossil fuel combustion, land use and land use change (deforestation). Yet our understanding of interactions between land use (change) and climate is still uncertain. Climate changes Spatial Planning contributed to the development of a system that allows both the best possible 'bottom-up' estimate of the GHG balance in the Netherlands, as well as independent verification 'top-down'. This system supports better management, i.e. reductions of GHG emissions in the land use sector. In this context it addressed a.o. the possibilities and spatial implications of second generation biomass production.

Programme Office Climate changes Spatial Planning

P.O. Box 1072
3430 BB Nieuwegein
The Netherlands
T +31 30 6069 780

c/o Alterra, Wageningen UR
P.O. Box 47
6700 AA Wageningen
The Netherlands
T +31 317 48 6540
info@klimaatvoorruimte.nl

www.climatechangesspatialplanning.nl