Viewls

Shift Gear to Biofuels

Results and recommendations from the VIEWLS project

November 2005

Achieving clear views on information concerning, and prospects of, biofuels for transportation

Preface

Biofuels are fuels made from an organic origin, as opposed to a fossil-fuel-based origin. This is an enormous advantage in a period where the undesired impacts of environmental changes are increasingly being experienced. The organic origin implies that the circle between environmental profit and loss is (about to be) closed. At the same time, the advantage of being an organic fuel is also a weakness: the production of the biomass resources, the production processes themselves and the use of the fuels in transport vehicles lead to varying emission figures, thus causing a lack of consensus concerning the degree to which the 'circle' is closed.

The fact that biofuels are produced from an organic origin also creates opportunities, especially for farmers and biomass producers. The new members of the European Union could benefit from this opportunity, creating a win-win situation for both existing and new Member States, i.e. employment in the agricultural sector and reduced environmental pressure in the transport sector – a sector confronted with continued increases in energy consumption and corresponding CO_2–eq. emissions.

Furthermore, if biofuels can be produced in the extended European Union (EU-25) countries, then both existing and new Member States can contribute to the trend reversal of oil import dependency. In order to achieve this, we need to discover how to minimise the market introduction costs of biofuels when entering the transport fuels market.

Having spent most of the past three years implementing the VIEWLS project, it has been interesting to see how clarity on these topics has been gained. The intense collaboration between all project partners, which originated from all corners of the European region (plus several from the North American continent!), provided a clear example on how to tackle complex subjects with such interesting potential, in order to contribute to a more sustainable Europe. The project results show that in order to achieve our objectives, strategic decisions need to be taken by all relevant stakeholders in Europe. They are now the ones in the driver's seat, and they hold the key to shifting gear to biofuels!

Eric van den Heuvel

Project Coordinator of the VIEWLS project

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PART 1: OVERALL FINDINGS AND RECOMMENDATIONS

1 Introduction

1.1 Scope of the project

The "Clear Views on Clean Fuels" (VIEWLS) project is supported by the European Commission and aims to increase our insight into:

- The economic and environment-technical performances of the various transport biofuels, both existing biofuels and those still under development[1].
- The biomass production potential in the Central and Eastern European region, and the possible biofuel trade chains that may develop from this within Europe.
- The opportunities for achieving the EC guideline on biofuels[2] at the lowest possible price.

The VIEWLS project began in February 2003 and was finalised in April 2005. The following results reflect the various tasks within the project[3]. The recommendations are partially derived as a result of communications with representatives of the European Commission and the biofuel stakeholders in Europe.

2 Results

The results describe:

- The economic and environment-technical performances of biofuels.
- The production potential in an intra-European trading situation with Eastern and Central Europe
- Biofuel implementation scenarios

2.1 Economic and environment-technical performances of biofuels

The project reviewed the relevant biofuel information from literature that has been publicly available over the past few years, and formed this into a structured overview, thus allowing an estimate to be made of the economic and environment-technical performances of biofuels. This review differentiated between biofuels that are currently available (e.g. biodiesel, pure plant oil (PPO), bioethanol from sugar and starch, and biogas) and those still under development (e.g. ethanol from cellulose-based raw materials and bio-FT-diesel). The most important results from this review are:

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[1] VIEWLS includes the following biofuels: bioethanol, bio-ETBE, biomethanol, bio-MTBE, pure plant oil (PPO), biodiesel, bio-Fischer-Tropsch diesel, bio-DME, biogas, bio-hydrogen, and biosynthetic natural gas.

[2] The European Commission's Biofuel Guideline includes indicative percentages for the biofuel share in the transport fuel market in Europe: 2% in 2005 and 5.75% in 2010.

[3] Two North American and 17 European project partners participated in this project. SenterNovem, in the Netherlands, carried out the project coordination. Information on VIEWLS can be obtained from www.viewls.org.

Taking the entire production and application chains into account, current biofuels lead to lower greenhouse gas emissions than their fossil-based alternatives (petrol or diesel).
The climate balance is positive, even for today's first-generation biofuels. Greenhouse gas emissions (expressed as gram CO_{2-eq} per kilometre driven) are lower than for their fossil-based counterparts. The studies reviewed reported various performance values between the different biofuels and even within one type of biofuel. This is primarily explained by the varying circumstances for the harvesting and production processes, but also by the differences in starting points and assumptions made by the various studies. As a result of this review, VIEWLS allocated 'reference values' for each of the biofuels. VIEWLS recommend that these 'reference values' be used as the starting point for further policy evaluations, and that the uncertainty margin be taken as 30%. In general, the greenhouse gas emissions from today's biofuels are 30-50% lower than those of their fossil-based counterparts.

The review shows that future biofuels will reduce greenhouse gas emissions even further. The VIEWLS reference values indicate that greenhouse gas emissions, taken over the entire production and application chains, are 50-90% lower than those of fossil fuels. Here too, VIEWLS recommends an uncertainty margin of 30%, partly due to the uncertainties concerning technological developments. The review also shows that future biofuels will largely be produced from cellulose-based raw materials, thus replacing plant oil, sugar and starch as raw materials. The final report contains a list of the exact VIEWLS reference values for each future biofuel.

Biofuels still lead to higher transport costs

The production costs for biofuels are higher than those for traditional petrol and diesel.[4] This applies to the current biofuels and is also expected to apply to the future biofuels. The latter is primarily caused by the technological development stage that these fuels have currently reached. A structural reduction in production costs for these fuels is only expected in the long term. At current oil prices (see also footnote 4) the production costs are 2-3 times higher for the current biofuels and will be 2-4 times higher for future biofuels[5]. Recent extreme oil prices (over 60 US$ per barrel in September 2005) have a positive effect on the difference between the production costs. Apart from the production costs, transport costs (expressed in euro per kilometre[6]) are also an important parameter, and include all costs necessary to move a car one km; fuel costs are just one item on the list. The result is that the extra costs – per km driven – of biofuels, compared to their fossil-based counterparts, are much smaller: between 3% and 29% for the current biofuels, and 1-100% for future biofuels[7].

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[4] For the current biofuels, VIEWLS assumed that the oil price fluctuates between 25-35 US$ per barrel of crude oil; for future biofuels this fluctuation is assumed to be 35-45 US$

[5] Based on biomass production levels in the CEEC region and under the assumption that future fuels will have expected learning curve developments.

[6] NB: this analysis was implemented excluding any relevant taxes.

[7] This high price is caused by the high cost estimates for biomethanol. The transport costs for the second most expensive future biofuel (according to the analysis) is 38% more expensive that its fossil-based alternative.

The costs of avoiding CO_2-eq. emissions will drop considerably, to acceptable levels, over the next few years.
The current biofuels are characterised by higher costs per ton of avoided CO_2-equivalents. The review revealed that the costs are generally 300-700 euro per ton CO_2-eq., although some studies indicated exceptions, both above and below these amounts. These high costs are caused by higher production costs, but primarily by the relatively limited CO_2-eq. benefit. The study review showed that, in the long term (after 2010), reduction costs could fall to levels between 40 and 200 euro per ton CO_2-eq. This is mainly due to (i) improved production methods for the current biofuels, with lower costs and better CO_2 reduction, and (ii) the arrival of biofuels produced from cellulose-based raw materials, which are characterised by significantly higher CO_2-eq. reductions. The aforementioned data is also based on certain price levels (see footnote 4) for crude oil that are lower than those of September 2005. At these price levels for crude oil, several biofuel options are already competitive, resulting in negative CO_2 reduction costs.

2.2 The production potential, plus intra-European trade opportunities between Eastern and Central Europe

The new Member States on the eastern side of the European Union offer prospects for growing raw materials to produce biofuels. In the light of its ambitious objectives to considerably expand the amount of sustainable energy used in Europe[8], it's interesting to estimate the extent to which land areas in the Central and Eastern European (CEEC) region could contribute to making the necessary raw materials available for biofuel production. The VIEWLS project developed a methodology for estimating regional biomass production potential, and for testing this against various scenarios[9]. These scenarios are based on possible important developments that could have a significant effect on the European agriculture sector, and could lead to certain land-use changes. The scenarios assume that the food needs of the population are met first, plus any need for wood products. Only then is the amount (and quality) of land determined that would become available for growing biomass crops suitable for energy applications. Information at NUTS-3 (Nomenclature of Territorial Units for Statistics) level was analysed for the various countries in order to reach a detailed estimate of the potential. The most important results from this analysis are:

In an agro-intensive scenario (currently not yet applicable in the CEEC region), 35-44 million hectares of land could be available for biomass production in 2030, which could lead to a annual biomass potential of 6-12 EJ.
Using a scenario revolving around 'regionality' and maintaining agricultural production systems at the present level of productivity in CEEC, more land would be required for food and wood production, leading to a possible biomass reserve of between 2.5 and 6 EJ. NB: in the year 2000, the total energy

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[8] In 2010 the EU would like to see 12% of the total energy consumption generated by renewable energy.

[9] The biomass potential is determined by five scenarios: V1 Free world trade – no market restrictions between the EU and the rest of the world for agricultural products, high-tech advanced agricultural production system; V2 Regionally oriented policy – unequal economic developments within Europe, trade barriers between West and Eastern European markets, current agricultural production system in CEEC maintained; V3 Common Agricultural Policy used throughout the EU, high-input agricultural management system; V4 Fortress Europe – no internal trade barriers, own EU market is protected, high-tech advanced agricultural production system; V5 Ecological Europe – focusing on sustainable development, promoting ecological agriculture.

consumption for the CEEC region amounted to 6 EJ. It is therefore clear that the production of biomass can play an important role in increasing Europe's sustainability levels: the energy content of the biomass that could be produced in the CEEC is greater than the energy demand, and thus offers opportunities for exporting to Western Europe. It's interesting to note that the scenario concerning a shift towards organic agricultural production methods leads to a smaller biomass potential.
'Cost-supply' curves were defined for the various scenarios. The circumstances within the scenarios lead to varying qualities of land being required for food and fodder production. The agro-intensive scenario continues to have a lot of high-quality land available for biomass production, which leads to lower biomass production costs. Biomass from lignocellulosic crops can be produced for around 2€/GJ. Higher costs (up to 10€/GJ) are estimated for other raw materials and scenarios.

Analysis shows that significant and relevant amounts of biomass could be produced at acceptable costs, but that amounts used in the analysis cannot currently be achieved. Therefore strategic policy decisions need to be prepared in order to ensure that these potentials within the CEEC region can be achieved. An investment boost is required for the agricultural sector to increase the productivity, and a transition will need to be made towards a more efficient agricultural production and management structure.

This analysis into production potential clearly shows that a trade flow in biomass could be set up from Eastern Europe to Western Europe. This is why a separate analysis was implemented, to gain better insight into the possible logistical and infrastructure opportunities for this trade flow. This analysis led to the following conclusion:

The existing European transport network infrastructure (road, rail and water) is suitable for exporting biomass from Central and Eastern Europe. Where possible, biomass could be converted to biofuel in Central Europe, because transporting the biofuel would be less expensive than transporting the raw biomass and then converting it in Western Europe. The costs would then vary between 6.4 and 9€/GJ_{HHV}.

2.3 Biofuel implementation scenarios

In order to give a proper estimate of the role played by biofuels in Europe, VIEWLS also implemented a study to develop elements for a cost-efficient biofuel strategy (in addition to the study described above). This study also considered the alternative use of biomass outside the transport sector, e.g. for generating electricity and heat, and differentiated between cost-efficient input in the short term and in the longer term. The most important conclusions resulting from the calculations of the models used are:

The models predict that in the long term – certainly to 2020 - the current-generation biofuels could play an important role in the biofuel market, due to their favourable production costs. The next generation of biofuels (primarily those using gasification of lignocellulose-based raw materials) is expected to gradually increase (up to 2010) and then strongly increase its market share (from 2010 onwards). The price level for this new generation of biofuels is based on a barrel of crude oil costing around 60-100 US$ per barrel.

The greenhouse gas reduction potential for the new generation of biofuels is higher (85-92%) than that for the current biofuels (39-46%). The models indicate that they could be produced for around 8 €/GJ, which makes them comparable with the production costs for fossil fuels of 7 €/GJ (at a crude-oil price of 40 US$). Note that this is based on the following assumptions:

- A successful development and upscaling of the gasification technology.

- Sufficient lignocellulosic biomass being produced in Central and Eastern Europe, based on agricultural developments, such as those described in the previous section.
- The new generation of biofuels meet the latest, stricter fuel specifications that apply within the EU.

In addition to using specially grown biomass crops for biofuels, the development of lignocellulose-based biofuels means that fewer residues and waste products will be required. The models show that the agricultural area in Europe need not be a limiting factor, provided that it starts to develop in preparation for intensifying the agricultural sector in Central and Eastern Europe. Under these conditions the production of food crops, wood production and raw materials for bioenergy are all possible. The year 2030 could see biofuels taking a 20% share of the transport fuel market, based on the amount of land available (under the aforementioned conditions and thus depending on which scenarios are adopted).

In addition to model analysis of the biofuel sector, a broader analysis was also implemented, which focused on the sales opportunities for biomass in other parts of the energy system. Using biomass to generate electricity and heat has always been the most important motivation for developing bioenergy and, from a cost-effectiveness perspective, this will remain so unless a specific energy-sector policy is developed. The various sales opportunities for biomass, both for stationary and mobile systems, can lead to undesirable competition within the biomass sector. A careful strategy to achieve the efficient use and development of bioenergy, both for the transport and electricity/heat markets, is therefore highly recommended.

3 Conclusions and recommendations

The following conclusions and recommendations are derived from the results of the various VIEWLS studies.

The environmental performance (particularly the greenhouse gas reduction potential) of biofuels is positive and will increase in the years to come: through improvements that are specific to the fuel chain and optimising performance, and through the creation of new-generation biofuels.

The production costs of current biofuels are approaching the price level of fossil-based fuels, especially when based on biomass produced in the CEEC region, partially due to recent price increases for crude oil. The production costs of new-generation biofuels are slightly higher because, as yet, there has been no optimisation of technological development and upscaling, as well as improved corresponding lignocellulosic biomass production optimisation.

The costs of greenhouse gas reduction are clearly more favourable for new-generation biofuels, which is caused by the higher greenhouse gas savings due to the use of lignocellulose-based biomass.

Environmental and economic performance	Potential and trade in CEEC region	Biofuel market introduction model
Lower GHG emissions Further reduction with future biofuels	Potentially up to 6-12 EJ biomass reservoir at 35-44 Mio ha. In agro-intensive scenario	High share of biofuel possible (20% in 2030) Sufficient land for biofuels available
Higher driving costs But almost competitive with oil price increases	Low biomass production cost possible < 2 €/GJ Based on perennial lignocellulosic biomass	In short-term least-cost conventional biofuels Future Ligno-fuels become important
GHG mitigation costs can drop to 40 €/tCO2-eq. Shift from oil crops to lignocellulose biomass	Export from CEEC to WEC with existing key transport corridors	Break-even points for biofuels at 40-80 $/bbl crude oil

Table 1: Overall results from the VIEWLS project

Central and Eastern Europe could become the 'biofuel store' of the EU. If suitable strategic decisions are taken for the agricultural sector, sufficient agricultural areas could become available for producing biomass, without endangering the production of food crops and wood for other applications.

The available infrastructure facilities are already present to accommodate the trade in biomass and, preferably, to allow biofuel trade between Western and Eastern Europe at an acceptable price.

There is still a risk of competition between biomass for electricity and heat production and biomass for the transport sector. Careful strategic alignment will be required (at both national and European levels) to ensure synergy of the development.

The elements for an efficient biofuel implementation strategy consist of:

- Further optimisation of current biofuel performance (based on plant oil and sugar/starch). Biofuels can then become 'market-proof' and biofuel manufacturers will gain insight into the market criteria necessary for future improvements.
- Long-term support for the development of thermo-chemical and enzymatic conversion routes for lignocellulosic biomass in the new generation of biofuels is required in order to achieve high greenhouse gas reduction levels and be economically attractive.
- Strategic policy activities are required in order to make suitable agricultural areas in Central and Eastern Europe available for biomass production.

Choices need to be made at European level to define the priority focus for the future development of biofuels: i) focus on the lowest possible production costs for biofuels, ii) focus on the highest possible reduction in greenhouse gas emissions, or iii) focus on the highest possible energy efficiency for the land areas available. These decisions will need to be made in consultation with all relevant stakeholders, because each alternative leads to a different mix of biomass options to be developed. The possible resulting options are:

- The continued use of current-generation biofuels: transport biofuels based on oil, sugar and starch, plus the use of cellulose-based biomass to generate electricity and heat.
- Switching over to a situation in which cellulose-based raw materials dominate the production of transport fuels and bioenergy.
- Primarily using biomass to generate electricity and heat, due to the strong focus on cost-effectiveness for CO_2-eq. savings.
- Primarily using biomass in the transport sector because there are no other significant CO_2 reduction options available for this sector, and in the electricity sector where other sustainable options, other than bioenergy, are available.

Part 2:
Executive summaries of the VIEWLS Work Package results

4 Work Package 1 Stakeholder analysis and involvement

4.1 Introduction

For the VIEWLS project an internet-based questionnaire on biofuels was distributed among a large group of stakeholders in the European Union, Accession Countries and the America's (second half of 2003). The purpose of the questionnaire was to collect information on stakeholders' opinion on biofuel-related topics, including the future potential of biofuels, and the drivers and barriers to market introduction. The main results, summarised in the following sections, should only be regarded as indicative because no detailed statistical analysis was performed due to the difference in representations from the various countries and stakeholders groups.[10]

In addition to the questionnaire, European stakeholders were invited to be actively involved in the VIEWLS project, via access to the VIEWLS virtual office (at www.VIEWLS.org). Over 450 organisations registered for access, both inside and outside Europe. The virtual office allowed stakeholders to access resources such as i) the library with biofuel documents supplied by the stakeholders themselves and by the VIEWLS project team, plus VIEWLS-related documents; ii) the Discussion Lounge, where questions could be raised for further debates; iii) the Links page, where stakeholders could find links to upcoming events and relevant organisations. An important part of the virtual office was the opportunity to review draft VIEWLS documents, so that the VIEWLS partners could incorporate stakeholders' comments into the final version of reports.

4.2 Results from the stakeholder questionnaire

4.2.1 Main conclusions regarding general information of respondents

In total 1,422 questionnaires were distributed, of which 314 were returned, which resulted in a response rate of 22%. Overall the largest response was from 'Industry and Trade' (38%), closely followed by 'Knowledge Centres' (32%). The responses from the other two stakeholder groups, 'Government' and 'NGO and Other Organisations' were lower (13-14%). Of all respondents, 74% were already active in the field of biofuels and 17% were considering entering this field. With respect to the entire biomass to biofuel chain, 52% of the respondents were active in the biomass to biofuel conversion process.

4.2.2 Main conclusions regarding knowledge about and role of biofuels

The respondents mainly had expert knowledge about biodiesel/RME (41%), bioethanol (38%), biogas (29%) and pure vegetable oil (23%). Regarding the short-term role of biofuels in the EU (before 2010), most respondents expected widespread use as a fossil-fuel blend for biodiesel and bioethanol. A minor share in niche markets was expected for biodiesel, bioethanol, biogas and pure vegetable oil. A significant market share (in pure form) was expected for biodiesel.

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[10] The results described here are reported in the Work Package 1 report "Stakeholder views on biofuels" – March 2004. The report is produced by COWI and SenterNovem. All VIEWLS project partners have contributed to the activities in work package 1.

Regarding the long-term role of biofuels in the EU (after 2010), widespread use (as a blend in fossil fuels) was expected for bioethanol, biodiesel, bio-FT -diesel and biogas. A minor share in niche markets was expected for biogas, biodiesel, 'pure vegetable oil and bioethanol. A significant market share (in pure form) was expected for biodiesel, bioethanol, bio-FT-diesel and biogas.

4.2.3 Main conclusions regarding drivers and barriers

The three dominant drivers for the introduction of biofuels are i) reduction of greenhouse gas emissions (87%), ii) diversification of energy sources (77%), and iii) less dependency on fossil fuels and fossil fuel import (76%). The least important driver is financial gain (43%). For accession countries this dominance was slightly different: the most important drivers are reduction of local emissions and agricultural, regional and/or local development. The reduction of greenhouse gas emissions is the main driver for all stakeholder groups. The creation of jobs/employment is a prominent driver for government (75%). For industry, financial gain and a green image (both 64%) are important drivers compared to other stakeholder groups.

The most promising biofuels for achieving the EU objectives in the respondents' countries, for all stakeholder groups and countries, are biodiesel/RME (38%), bioethanol (28%), bio-Fischer-Tropsch diesel (9%) and biogas (8%).

Regarding the barriers to market introduction of biofuels, the majority of stakeholders chose to answer detailed questions for bioethanol and biodiesel. Economic barriers are the main barriers for bioethanol (89%) and biodiesel (77%). specifically, the most important economic barriers are low fossil fuel prices, lack of national tax exemption, and production costs or price of biomass.

For ethanol, technical barriers are relevant to 41% of the respondents, although 50% disagrees. The main technical barriers for ethanol are conversion technology of biomass, availability of biomass and quality of biomass and/or biofuels. Quite a large proportion of respondents indicated that blending fossil fuels with biofuels, vehicle use of biofuels/need for vehicle adaptation and distribution of biofuels are not barriers. Technical barriers for biodiesel are not relevant to 71% of the respondents.

For ethanol, 40% indicated that social/institutional barriers are important, although 47% disagrees. For biodiesel, 49% agrees and 34% disagrees. The most mentioned barriers for both biofuels are the lack of interest from large industries, implementation of EU directives into national targets, the lack of local, regional and national commitment to Kyoto, and the lack of information on biofuels. The general public's acceptance of biofuels, and environmental group opposition to biofuels, are not seen as barriers by a large percentage of respondents. With respect to environmental barriers for ethanol (85%) and biodiesel (75%), the majority indicated that these are not barriers.

4.2.4 Main conclusions regarding biomass resource potential

Between 2005 and 2010 residues (57%), energy crops (48%) and waste (26%) are regarded as the main biomass resources for biofuel production. On the contrary, few people consider sewage sludge (29%), manure and waste (both 22%) as biomass resources for biofuel production.

4.2.5 Main conclusions regarding information sources

All information sources were generally used by all stakeholders, the most popular being networks and colleagues (56%), internet and e-mail newsletters (52%), and scientific journals and reports (50%). With respect to the various types of studies on biofuels, cost studies (75%), biomass potential studies (74%), energy system studies (72%) and LCA studies (55%) were used by stakeholders, but 23% indicated that they do not use LCA studies.

5 Work Package 2 Environmental and economic performance of biofuels[11]

5.1 Overview of biofuels and resources

According to the EU Biofuel Directive the use of biofuels in the transportation sector should be strongly increased throughout Europe over the next few decades. The implementation of the European Directive 2003/30 "Promotion of the use of biofuels or other renewable fuels for transport" by the European Parliament and the Council is the main driving factor behind this analysis. The Directive specifies that "Member States should ensure that a minimum proportion of biofuels and other renewable fuels is placed on their markets, and, to that effect, shall set national indicative targets. A reference value for these targets shall be 2% calculated on the basis of energy content, of all petrol and diesel for transportation purposes placed on their markets by 31 December 2005 and 5.75% by 31 December 2010".

5.1.1 Purpose of the work

The purpose of this work package was to obtain and present clear data and reliable information to outline environmental and economic performance of different biofuels. Based on a standardised review of the most relevant international studies on transportation systems using biomass, the multidisciplinary team created a common format ("Study Fact Sheets") to present an estimation of ranges for the environmental and economic performance of different biofuels documented in the most relevant international studies.

The environmental and economic performance may be used by the various stakeholders as an information source for future activities regarding the use of biofuels in the European transportation sector. The environmental and economic performance of the various biofuels could be used to support activities in the use of biofuels in the transportation sector, according to this Directive.

The choice of the considered biofuels was made while referring closely to the European Directive. "Biofuel" means liquid or gaseous fuel for transportation produced from biomass. "Biomass" means the biodegradable fraction of products, waste and residues from agriculture (including vegetal and animal substances), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste. The following biofuels were considered:

- ***bioethanol***: ethanol produced from biomass and/or the biodegradable fraction of waste;
- ***biodiesel***: a methyl-ester produced from vegetable or animal oil/fat, of diesel quality;

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[11] The working group was formed by: Manuel Varela, CIEMAT, Spain; Carmen Lago, CIEMAT, Spain; Gerfried Jungmeier, Joanneum Research, Austria; Kurt Könighofer, Joanneum Research, Austria; Jens Dall Bentzen, COWI, Denmark; Thomas Odgaard, COWI, Denmark; Anke Swets, SenterNovem, The Netherlands; Eric van den Heuvel, SenterNovem, The Netherlands; Ann Segerborg-Fick, Stem, Sweden; Lazaros Karaoglanoglou, NTUA, Greece; Josef Rathbauer, BLT, Austria; Ingeborg Bolter, BLT, Austria; Theo de Lange, ECN, The Netherlands; Ruud Egging, ECN, The Netherlands; Warren Mabee, UBC, Canada; Etienne Poitrat, ADEME, France.

- ***biogas***: a fuel produced from biomass and/or from the biodegradable fraction of waste, that can be purified to natural gas quality;
- ***biomethanol***: methanol produced from biomass;
- ***biodimethylether***: dimethylether produced from biomass;
- ***bio-ETBE*** (ethyl-tertio-butyl-ether): ETBE produced on the basis of bioethanol. The percentage by volume of bio-ETBE that is calculated as biofuel is 47%;
- ***bio-MTBE*** (methyl-tertio-butyl-ether): a fuel produced on the basis of biomethanol. The percentage by volume of bio-MTBE that is calculated as biofuel is 36%;
- ***synthetic biofuels***: synthetic hydrocarbons or mixtures of synthetic hydrocarbons, which have been produced from biomass. These are mainly Fischer-Tropsch diesel and synthetic natural (liquefied) gas derived from gasification of biomass;
- ***biohydrogen***: hydrogen produced from biomass, and/or from the biodegradable fraction of waste, to be used as biofuel. The biohydrogen can be gaseous or liquefied;
- ***pure vegetable oil***: oil produced from oil plants through pressing, extraction or comparable procedure, crude or refined but chemically unmodified, when compatible with the type of engine involved and the corresponding emissions requirements.

The following biomass resources were considered:

- ***energy crops***: lignocellulosic crops, oil crops, sugar crops, starch crops;
- ***residues***: forestry residues, agricultural residues, wood processing residues, construction residues, food industry residues;
- ***manure***: solid manure, liquid manure;
- ***sewage sludge***: sewage sludge from wastewater treatment;
- ***waste***: garden, fruit and vegetable waste, other organic waste, organic compound of MSW (municipal solid waste).

The most promising combination of these biofuels and resources for transportation service systems were analysed, whereas the propulsion systems of vehicles were: an internal combustion engine and a fuel cell with an electric engine. The analysis was carried out for different states of technological development, short-term technologies (before 2010) and long-term technologies (after 2010).

5.1.2 Methodology

The developed procedure was based on a review of the most relevant international studies to document existing data on the aspects of different biofuels. The stepwise approach consisted of:

- Collection of international studies,
- Identification of most "relevant" studies in a selection process,
- Review of "relevant" studies in standardised format,

- Overview of the environmental and economic performance in "Study Fact Sheet",
- Expert assessment to compare the environmental and economic performance documented in the "Study Fact Sheets",
- Environmental and economic performance for each of the biofuels chain in "Biofuel Fact Sheet", and
- Comparison of environmental and economic performance of the considered biofuels in "Summary Biofuel Fact Sheet"

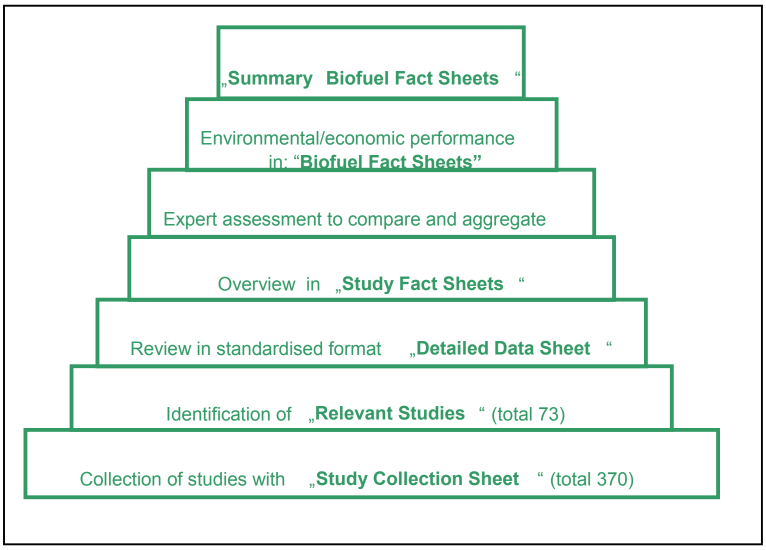

Figure 1. Stepwise procedure for the estimation of environmental and economic performance of biofuels based on reviewing existing international studies.

The environmental performance of biofuels describes in environmental units the lifecycle-based environmental releases of the different biofuels. "Lifecycle-based" means that the aspects are aggregated from the different processes through the entire lifecycle of biofuel – from the production of the raw material for the biofuel, transportation of the raw material, the conversion into biofuel, distribution of the biofuel, up to the final supply of a transportation service with a vehicle.

The economic performance of biofuels describes (in economic units) the costs of the production and use of different biofuels, starting with the production costs of the biomass, the transportation and processing costs through to the costs for the transportation service.

The environmental and economic performance depend very much on the specific characteristics and boundary conditions of the lifecycle of the different biofuels, e.g. country, resource, vehicle, propulsion system, state of technology. These characteristics were documented clearly and reflected in the resulting environmental and economic performance of the biofuels.

Based on a lifecycle approach, the study considered the overall environmental releases of the construction, operation and disposal of the transportation services, as well as from the use of by-products. For comparison the system boundaries of transportation systems based on fossil fuels also include the avoided reference use of the biomass or the agricultural area. The reference use of the biomass describes what happens with the biomass, if it is not used for a biofuel; the reference use of the agricultural area describes what happens on arable land, which is not used for energy crop production; e.g. in the case of forest residues, the reference biomass use is natural decomposition and, in the case of short-rotation forestry, the reference area use is land that has been set-aside. The reference use of fossil energy, e.g. natural gas, is that it remains in the ground, which has no effect on environmental releases.

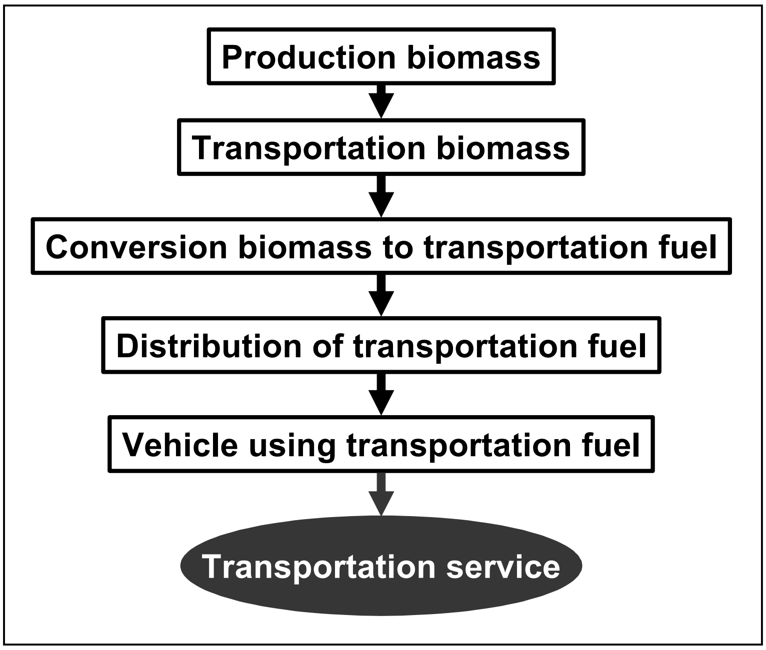

Figure 2. The five generic process steps for lifecycle-based considerations

The various transportation systems provide a transportation service for people. The measure of the functional output of the considered transportation systems is the environmental and economic performance referring to a transportation service of people in a passenger car over a distance of 1 km. Therefore the environmental performance was given for:

- CO_2 and $CO_{2\text{-eq}}$ emissions in grams per driven kilometre (g/km), and
- Primary energy demand in Megajoule per driven kilometre (MJ/km).

The economic performance was given for:

- Fuel costs at the filling station in Euro per Gigajoule [€/GJ], and
- Total driving costs per kilometre [€/100km].

Finally, the mitigation costs per tonne of avoided CO_2-eq and CO_2 were calculated based on the difference between the emissions, plus the total driving costs between biofuel and conventional fossil transportation systems.

Based on the results of the study review the expert assessment estimates ranged between the threshold values for the environmental and economic performance given by the two “threshold values” and the “reference value”.

Results of the study review are given in the common format of the "Study Fact Sheet", in which the environmental and economic performance of the various biofuels is shown together with the characteristics of the applied methodology. The executive summary concentrates on environmental and economic performance documented in the "Summary Biofuel Fact Sheet".

5.1.3 Environmental performance

The environmental performance depends very much on the specific characteristics of the lifecycle of the different biofuels, e.g. country, resource, vehicle, propulsion system, state of technology. These characteristics are covered by the reasonable ranges. But in general it is possible to conclude that most of the biofuels have already significantly reduced greenhouse gas emissions compared to petrol and diesel.

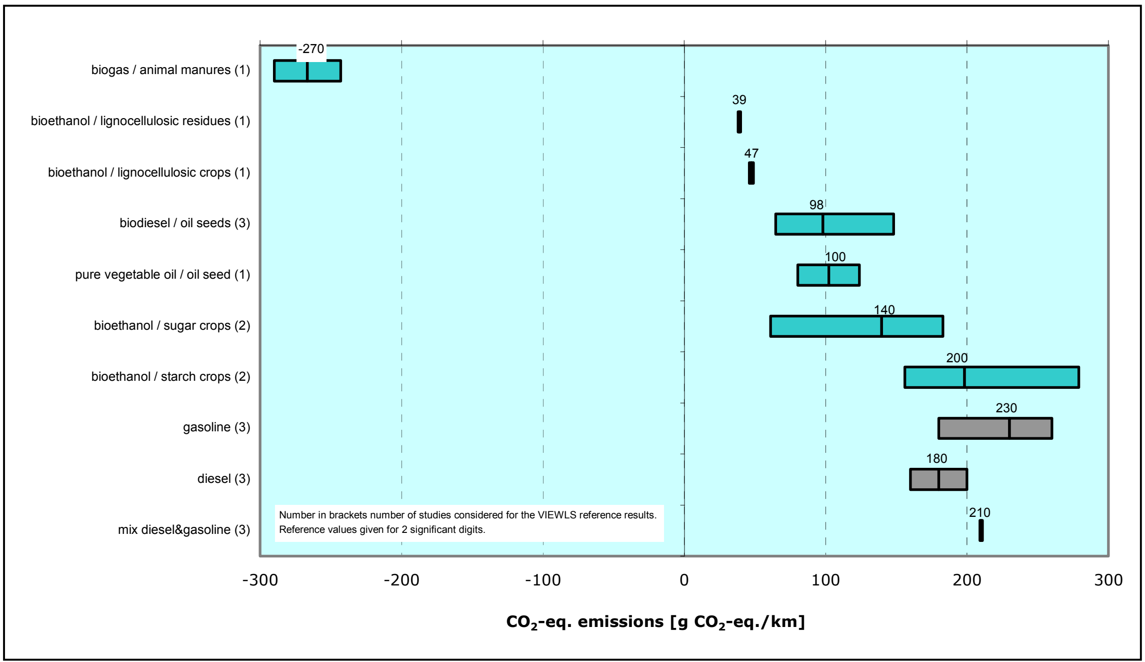

Figure 3. Threshold and reference values of the expert assessment based on study review for environmental performance in terms of CO_2-eq emissions; passenger car, technology <2010

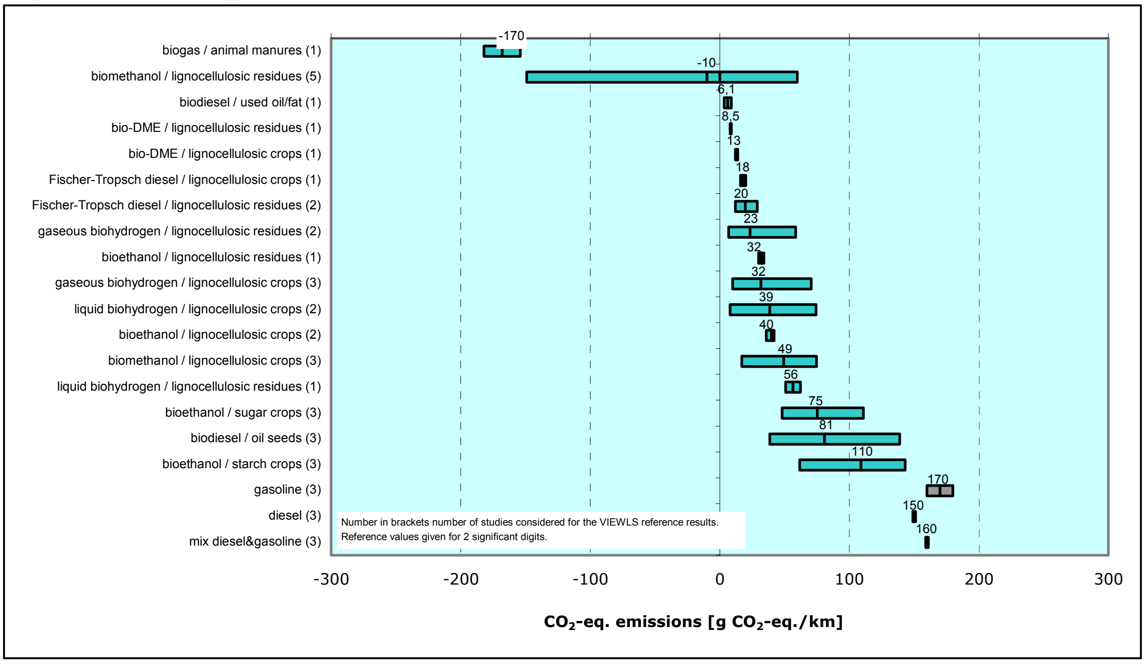

Figure 4. Threshold and reference values of the expert assessment based on the study review for environmental performance, in terms of CO2-eq emissions; passenger car, technology >2010.

Compared to conventional fuels (160 to 190 g CO_2-eq/km) most biofuels have significantly reduced greenhouse gas emissions (minus 270 to 140 g CO_2-eq/km), whereas further reduction might be achieved (minus 170 to 110 g CO_2-eq/km) for future biofuel technologies. The emissions may be minus, if the avoided emission of substituting conventional material with by-products from the biofuel production (e.g. rapeseed cake substituting for soy feed) and/or the emissions of the avoided reference use of the biomass, are higher than the emissions from the biofuel chain An example is biogas from manure, where CH_4 emissions from manure storage are avoided, if the manure is used to produce biogas.

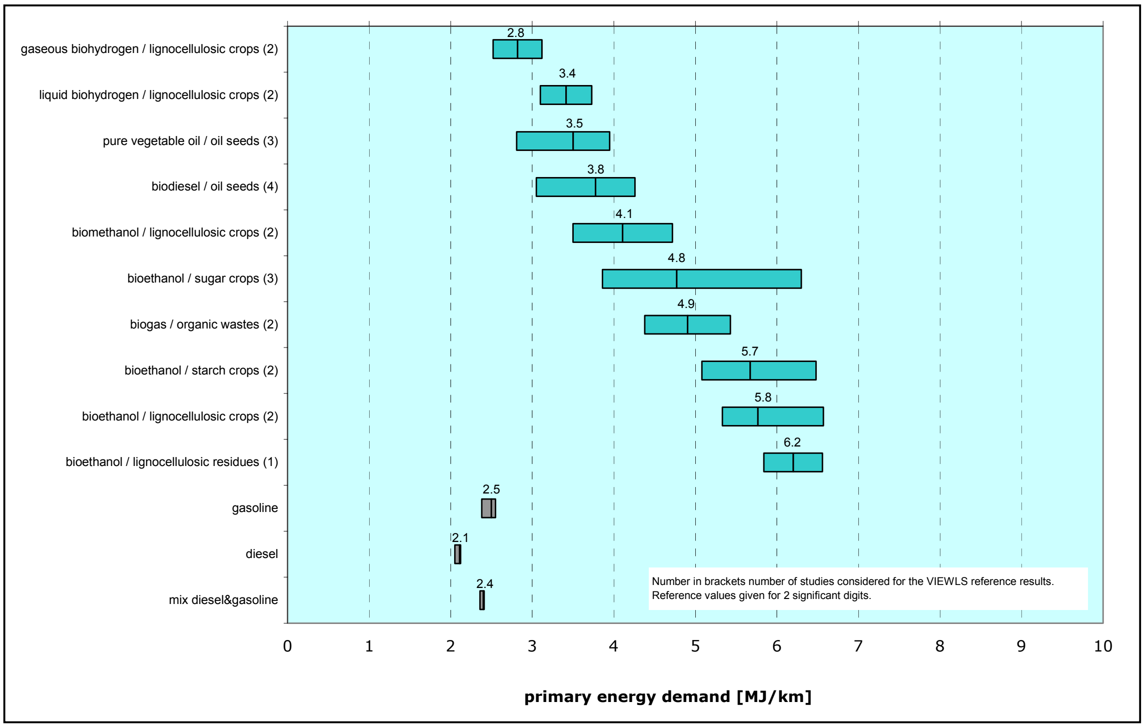

Figure 5. Threshold and reference values of the expert assessment based on the study review for environmental performance, in terms of primary energy demand; passenger car, technology <2010.

The primary fossil energy demand is significantly lower for biofuel compared to conventional fuels (minus 60 to 90%), as biofuels are derived from renewable resources. The total primary energy demand of biofuel (2.8 to 6.2 MJ/km) is generally higher compared to conventional fuels (2.1 to 2.5 MJ/km), as the energetic use of biomass is currently not so well developed, compared to fossil fuels. But there are ongoing developments to further reduce the total primary energy of biofuels (1.9 – 4.9 MJ/km).

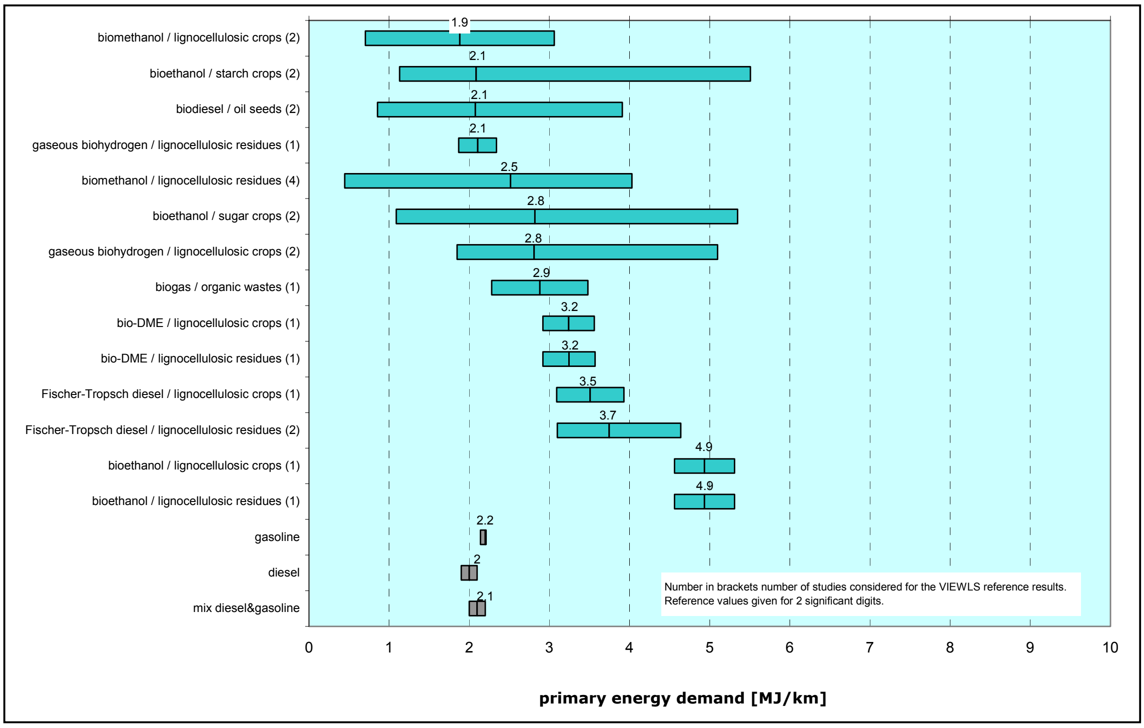

Figure 6. Threshold and reference values of the expert assessment based on the study review for environmental performance, in terms of primary energy demand; passenger car, technology >2010.

For some biofuels, e.g. Bio-MTBE and SNG, not enough studies are available, so further LCA work has to be conducted. With respect to environmental effects other than CO_2, $CO_{2\text{-eq}}$ and primary energy demand, it became clear that very few studies deal with these effects, therefore no conclusion on theses effects has been made after the study review. In that aspect it became evident that further LCA studies must be undertaken to provide data to create an overall picture of the environmental performance of biofuels.

5.1.4 Economic performance

Please note that the economic performance is presented in a before-taxes environmental, thus trying to avoid including the various fiscal regimes throughout the European Union for the various fuels.

The comparative analysis for biofuel costs at the filling station was carried out as a reference, to understand the aggregate results of the various biofuel chains, not to make a ranking between biofuels. Some biofuels have even higher costs at the filling station, but total driving costs are eventually cheaper, in terms of biofuel costs at the filling station.

The following graphs display the reference VIEWLS values and ranges for the various biofuel costs at the filling station ($€_{2002}$/GJ) in the short term (<2010) and long term (>2010).

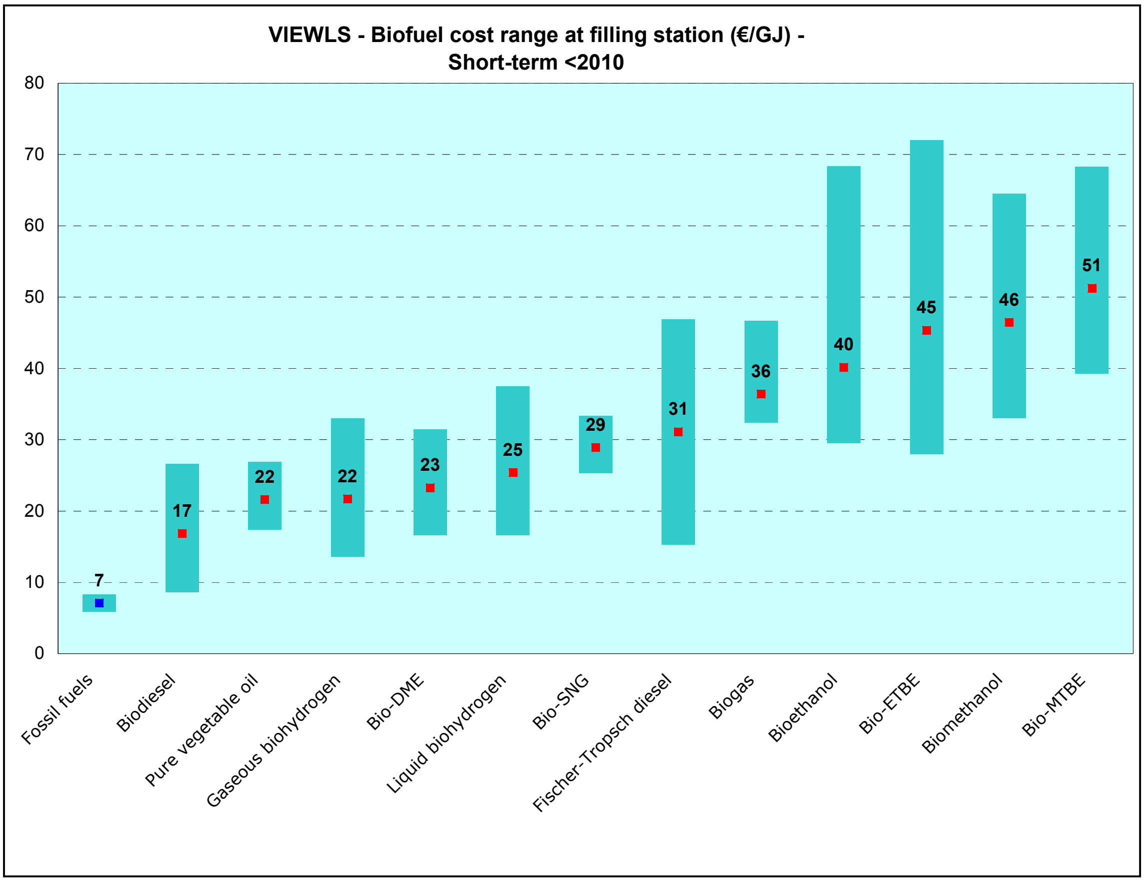

Figure 7. Reference values and cost ranges at the filling station (€$_{2002}$/GJ) in the short term.

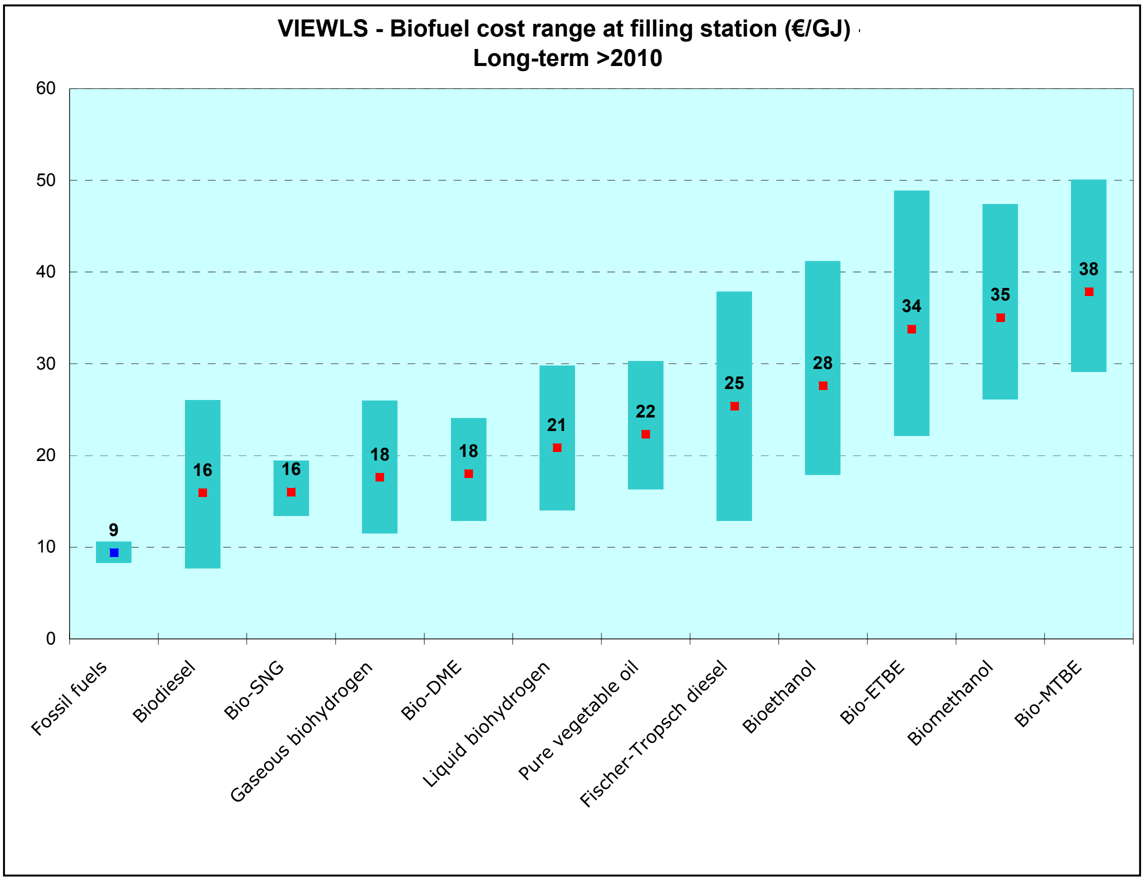

Figure 8. Reference values and cost ranges at the filling station (€$_{2002}$/GJ) in the long term.

What is noteworthy is the fact that biodiesel would be the only biofuel that could compete with fossil fuels in the future, always assuming very good conditions of production. The rest of the biofuels studied will still be nowhere near the production costs of the fossil fuels. Considering 'future conditions of production', the most promising alternative options, apart from biodiesel, would be gaseous hydrogen, DME and FT-diesel production.

Secondly, the comparative analysis for biofuel costs at the filling station was carried out per biomass resource. This breakdown shows a clearer picture of the different production pathways for the biofuels. From the biomass resource point of view, it is apparent that the foreground resources (in both short and long terms) should be organic wastes and lignocellulosic residues (forestry and agricultural). Apparently the biodiesel from organic wastes will be the most promising option for producing biofuels, even large-scale production of biodiesel from organic wastes could not be achieved in Europe. Lignocellulosic residues could be the first option to produce SNG, GH_2 or DME in the future.

The comparative economic performance of the biofuels as opposed to their fossil reference counterparts was also undertaken for the total driving cost scheme. As previously mentioned, this analysis was made in a 'without-tax approach' to try and avoid the effect of the different fiscal regimes across Europe. Total driving cost (€$_{2002}$/100 km) means the service cost for travelling a 100 km distance with a passenger car running on the analysed biofuels and fossil fuels. The following graphs present the comparative driving cost for short-term and long-term conditions.

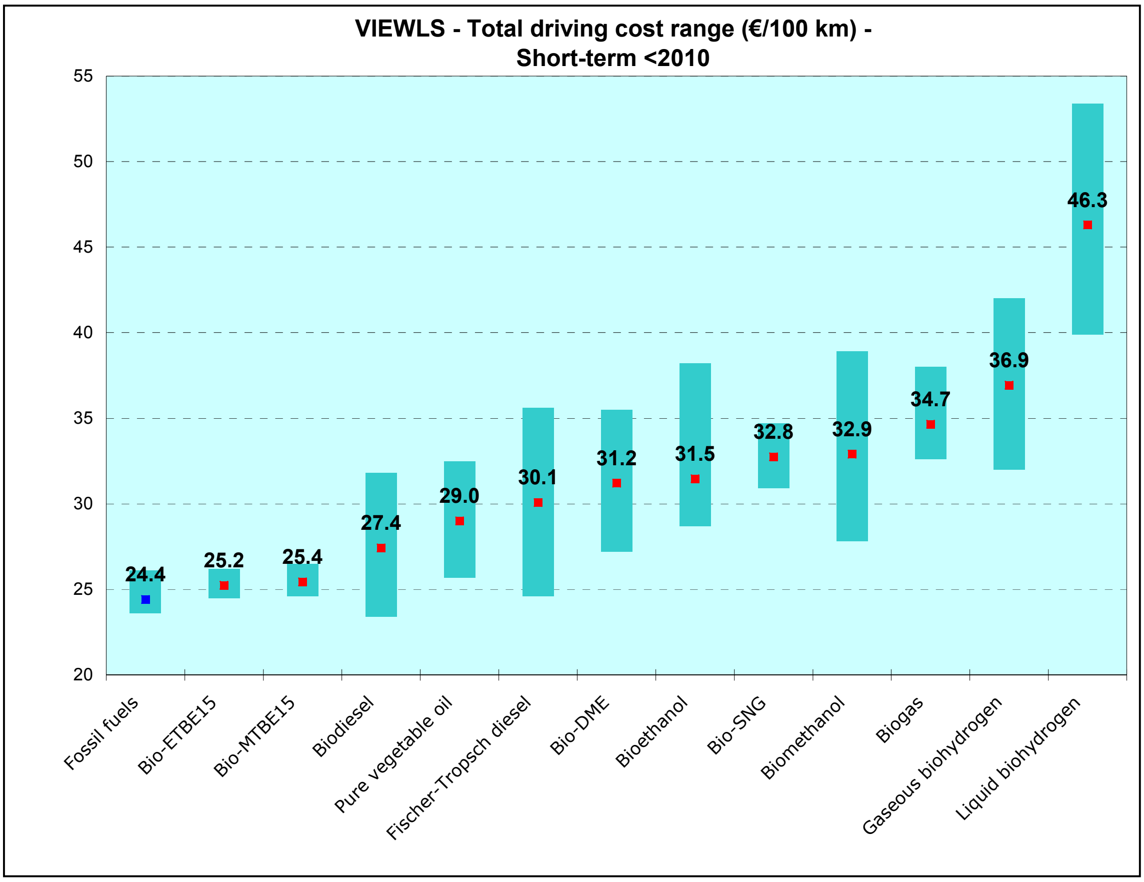

Figure 9. Total driving costs (€$_{2002}$/100 km) in the short term.

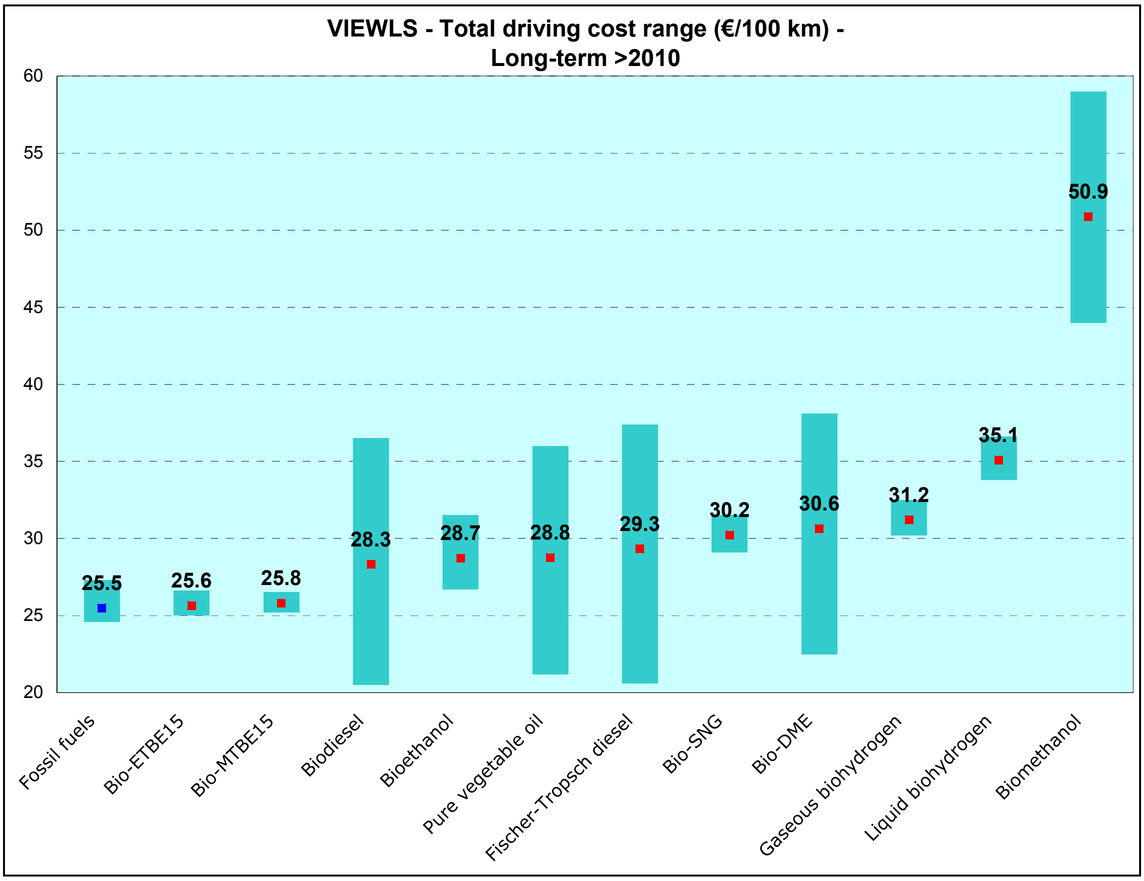

Figure 10. Total driving costs (€$_{2002}$/100 km) in the long term.

Seen from a short-term horizon (<2010), the passenger cars that could compete (under certain conditions) with a fossil fuel car are those fuelled with a mixture of up to 15% bio-ETBE and bio-MTBE. This could also apply to pure vegetable oil, but with very good conditions of biofuel production.

The long-term horizon (>2010) shows a slightly different situation. The passenger cars that could compete (under good production conditions) with a fossil fuel car are those fuelled with a mixture of up to 15% bio-ETBE and bio-MTBE, and those running on 100% biodiesel, vegetable oil, FT-diesel and bio-DME. This could also be the situation with bioethanol, under very good production conditions .

5.1.5 Greenhouse gas mitigation costs

The combination of environmental and economic performance of biofuels compared to conventional fossil fuels, leads to the mitigation costs. The greenhouse gas mitigation costs of biofuels for short-term technology range between 220 – 1,300 €/t $CO_{2\text{-eq}}$ avoided, depending on all the influences of the environmental and the economic performance; in long-term predictions this range might be between 39 and 2,200 €/t CO_2-eq.

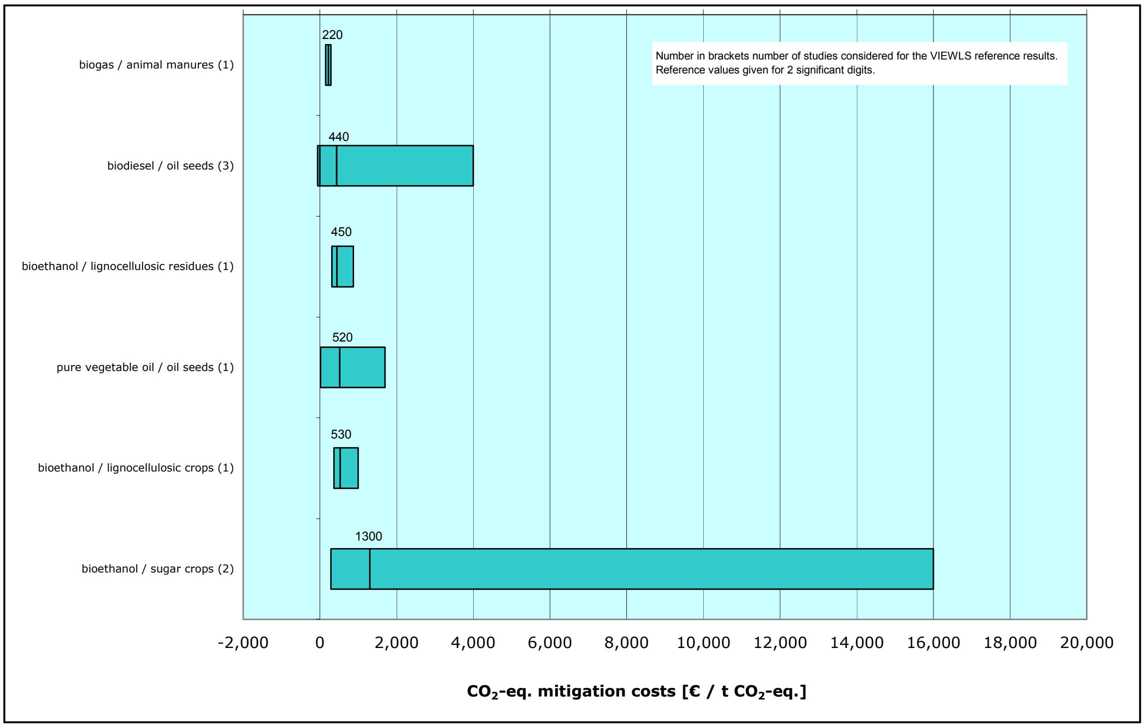

Figure 11. Threshold and reference values of the expert assessment based on the study review for greenhouse gas mitigation costs; passenger car; technology <2010.

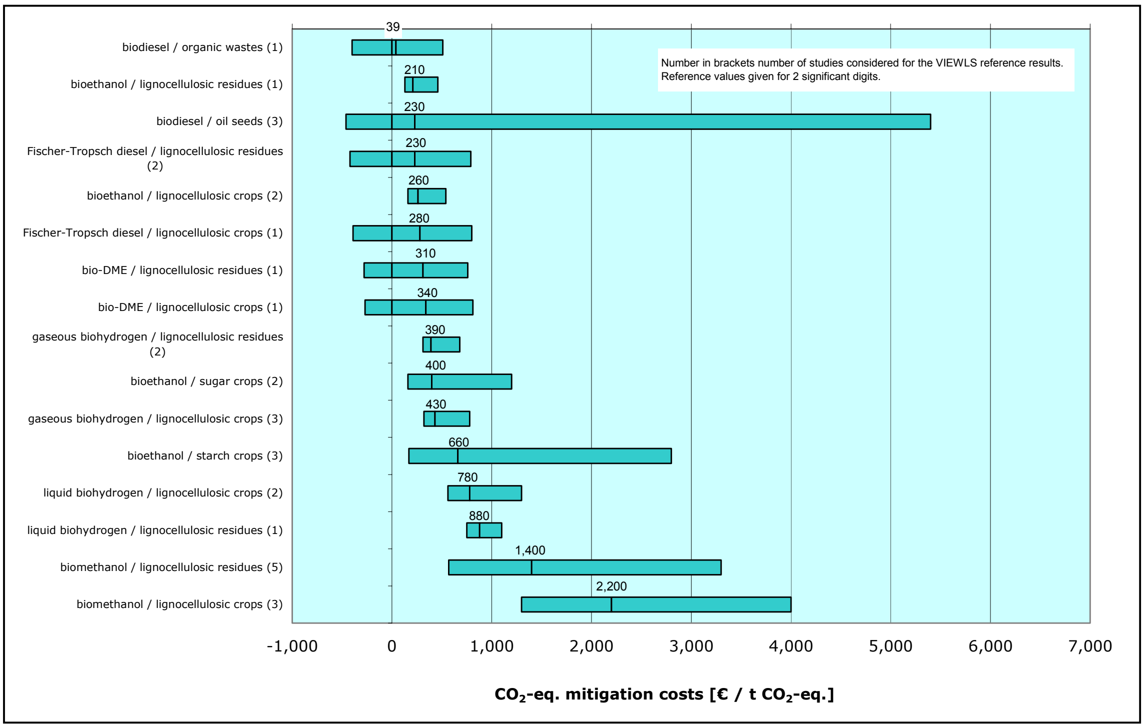

Figure 12. Threshold and reference values of the expert assessment based on the study review for greenhouse gas mitigation costs; passenger car; technology >2010.

5.1.6 Conclusions and recommendations

Many studies are available concerning the environmental and economic performance of different biofuels, especially for the most developed fuels: biodiesel and bioethanol. Most studies are based on different methodologies, and therefore cannot be compared easily. A comprehensive and generally accepted lifecycle approach was used in this work, which is considered to be the future most common and widely accepted approach to analysing the lifecycle environmental and economic aspects of biofuels, and is already used in the most recent biofuel studies in Europe and North America.

The performance of the various biofuels depends considerably on the specific characteristics of their lifecycle, e.g. country, resource, vehicle, propulsion system, state of technology. These characteristics were covered in the VIEWLS approach by using reasonable ranges.

The major influences on the environmental performance of the biofuels are: vehicle fuel consumption; use of by-products; reference use of the biomass or the agricultural land; amount of renewable energy in the energy system; propulsion system; biomass resource; uncertainty concerning future technology development; and many different biofuels from many different resources.

Based on the study review an expert assessment was made to bring these wide ranges down to threshold and reference values, in order to create a more structured picture when comparing the different biofuels, which results in the following conclusions:

Compared to conventional fuels (160 to 190 g CO_2-eq/km) most of the biofuels have significantly reduced greenhouse gas emissions (minus 270 to 140 g CO_2-eq/km) whereas, for future technologies of biofuels, further reduction might be achieved (minus 170 to 110 g CO_2-eq/km). The emissions may be minus, if the avoided emission of substituting conventional material with by-products from the biofuel production (e.g. rapeseed cake substituting soy feed) and/or the emissions of the avoided reference use of the biomass are higher than the emissions from the biofuel chain (e.g. avoided CH_4 emissions from manure storage).

The primary fossil energy demand is significantly lower for biofuels compared to conventional fuels (minus 60 to 90%), as biofuels are derived from renewable resources. The total primary energy demand of biofuel (2.8 to 6.2 MJ/km) is generally higher compared to conventional fuels (2.1 to 2.5 MJ/km), as the energetic use of biomass is currently not so well developed compared to fossil fuels. But there are ongoing developments to further reduce the total primary energy of biofuels (1.9 – 4.9 MJ/km).

The biofuel costs at the filling station (17 to 47 $€_{2002}$/GJ) are significant higher for short-term technologies than for conventional fuels (7 $€_{2002}$/GJ), whereas future developments indicate lower biofuel costs at the filling station (15 to 35 $€_{2002}$/GJ).

The total driving costs with biofuels are higher (25 to 46 $€_{2002}$/100 km) compared to conventional fuels (24 $€_{2002}$/100 km), but lower total driving costs are expected (25 to 35 $€_{2002}$/100 km) for future developments.

The greenhouse gas mitigation costs of biofuels for short-term technologies are spread over a wide range between 220 – 1,300 $€_{2002}$/t CO_2-eq avoided, depending on all the influences of the environmental and economic performance; for long-term prospects this range might be between 39 and 2,200 $€_{2002}$/t CO_2-eq.

One of the purposes of promoting biofuels is to reduce greenhouse gas (GHG) emissions. In general this analysis has confirmed the view that extensive use of biofuels will reduce GHG emissions, since most of the biofuels have already significantly lowered greenhouse gas emissions compared to conventional petrol and diesel. Another important aspect of biofuels is that they achieve savings in the consumption of fossil fuel resources. This characteristic is very important, considering the recent tendency towards high petrol prices. However, the enhanced use of biofuels competes with a number of other measures for reducing GHG emissions. The key issue therefore, from a policy point of view, is whether biofuels are a cost-effective measure for reducing GHG emissions. To analyse the cost-effectiveness of biofuels mitigation costs, i.e. the costs per CO_2-eq avoided, this has been estimated for a wide range of biofuels/resources. The results show that the extensive use of biofuels is rather costly way of reducing GHG emissions. In the short term (before 2010), mitigation costs are estimated at 440-1300 $€_{2002}$/t CO_2-eq.-avoided, depending on the resource used to produce biodiesel/bioethanol. In the long run (after 2010), mitigation is estimated to drop to a range of 210-440 $€_{2002}$/t CO_2-eq. avoided. CO_2 and the CO_2-eq. mitigation costs (in the long term) are low for technologies that use lignocellulosic residues and lignocellulosic crops. One may conclude that they are needed to develop these technologies.

The positive environmental performance of well-developed biofuels, such as biodiesel and bioethanol, make them attractive prospects for implementing the EU Biofuel Directive in the short term. However, in the medium-term, many new biofuels (e.g. synthetic biofuels and hydrogen based on renewable energy) seem to have an even higher potential for improving the environmental situation, and for supporting highly sustainable development of the European transportation system.

By considering the above conclusions, a series of recommendations can be established, i.e.:

- Studies on biofuels with a common and transparency approach are necessary in order to be able to compare the different biofuel chains and fossil fuels production.
- One of the handicaps of the biofuels production is the high price of the raw materials (sugar crops, starch crops or oil seeds). Additional research on new crops that can be used as biofuels is needed in Europe. Examples of such crops include Helianthus tuberosus or sorghum for bioethanol and Cynara cardunculus, Jatropha curcas, Ricinus communis, Brassica carinata or Elaesis guineensis for biodiesel.
- The use of crops that are less machinery-intensive and with fewer fertiliser and pesticide requirements could improve the environmental and energy balance of biofuels. It will also be necessary to introduce the use of biofuels into the agricultural machinery.
- For bioethanol, the cost and CO_2 emissions relating to energy consumption for the process is a major issue. This can be solved if the plant is not a stand-alone plant, but integrated into power plants or industry which has excess heat. These areas also have the right infrastructure.
- Bioethanol based on lignocellulose seems to be a promising route. However, the timeframe on when this technology will be fully developed is uncertain and a more specific analysis of these technology routes may be necessary.
- For sugar, starch crops and oil seeds, the environmental performance for the biomass production can be significant. Therefore a policy where these crops are adapted, as the most extensively grown, must ensure that the growth doesn't have a large negative environmental impact.

- CO_2 and the $CO_{2\text{-}eq}$ mitigation costs in the long term are low for technologies that use lignocellulosic residues and lignocellulosic crops. The conclusion is thus that we need to develop these technologies.
- It is recommended that parallel ways of reducing GHG emissions are also exploited with the large-scale introduction of biofuels in a European context. However, it cannot be ruled out that, under special favourable conditions, the production of biofuels could prove to be a cost-effective measure for reducing GHG emissions.
- The evaluation of new technologies (Bio-DME, Bio-SNG, FT-diesel or biohydrogen) that are not yet developed is generally presented in a positive way, but considering that figures relating to these technologies are sometimes ambitious, the analysis of these promising future technologies should be more deeply considered.

6 Work Package 3 Biomass production potential in Central and Eastern Europe under different scenarios[12]

6.1 Introduction

For the near future, increasing biomass use is considered to be essential in meeting the targets set out by the EU. As the potential from residues and wastes is already utilised to a high degree in the EU, a further future growth in biomass production should come from energy crops. A large increase in energy crop production requires large land areas in the EU. However, good land quality resources are limited in Europe and the production of biofuels will compete with food production and demands from the forest industry as well as from environmental protection and conservation considerations. At the same time, the ongoing expansion of the EU and the inclusion of the Central and Eastern European countries (CEEC) in agricultural and energy EU policies create potential difficulties as well as opportunities. In the future, rationalisation of the current agriculture in the CEEC is expected. This will lead to increased productivity and economic performance. On the other hand, unemployment and an increase in abandoned land are expected as well. This can put considerable pressures on the socioeconomic developments in rural areas in the CEEC, particularly because the agricultural sector still plays a major role for employment. Several countries in the CEEC region are characterised by huge land resources, comparatively low labour and agricultural production costs and relatively low productivity compared to Western European countries. If the bioenergy potential in the CEEC is found to be large enough, they could contribute significantly to the EU targets to increase the use of RES in total energy consumption. At the same time, a major new market – with potentially large positive influence on total bioenergy production and use in Europe – would emerge and rural development in the CEEC would be stimulated. Whether this concept is feasible and to what extent such targets could be obtained by trading biofuels between Eastern and Western Europe, needs to be investigated in a comprehensive way. The key question in this study is therefore to discover whether the bioenergy potential in the CEEC is indeed large enough to supply biofuels to the European market and under what conditions such potentials can be developed.

This study aimed to implement a regional biomass potential assessment for the CEEC, based on scenarios so that land-use changes over time are included in the analysis. As cost levels for biomass production need to be included in the analysis, final deliverables are the cost-supply curves from different sources (energy crops, residues) and production systems for the CEEC.

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[12] The activities in this work package have been implemented by Jinke van Dam, Andre Faaij (Utrecht Univeristy, Copernicus Institute for Sustainable Development, Department of Science, Technology and Society, the Netherlands), Magdalena Rogulska, Marzena rutkowska-Filipczak, Grzegorz Kunikowksi (EC-BREC/IBMER, Warsaw, Poland), Adam Ragoncza, Pal Pecnik (Hungarian Institute of Agricultural Engineering HIEA, Gödöllö, Hungary), Gheorge Valantin Roman, Lenuta Iuliana Bucata (University of Agronomic Sciences and Veterinary Medicine Bucharest, Faculty of Agriculture, Romania), Jan Weger, Kamila Havlickova (RILOG – Silva Tarouca Research Institute for Landscape and Ornamental Gardening, Department of Phytoenergy, Pruhonice, Czech Republic).

6.2 Methodology

In this study, a regional biomass potential assessment was implemented for the CEE countries of Estonia, Lithuania, Latvia, Poland, Romania, Bulgaria, Hungary, Czech Republic and Slovakia. A general overview of the methodology used is shown in Figure 13.

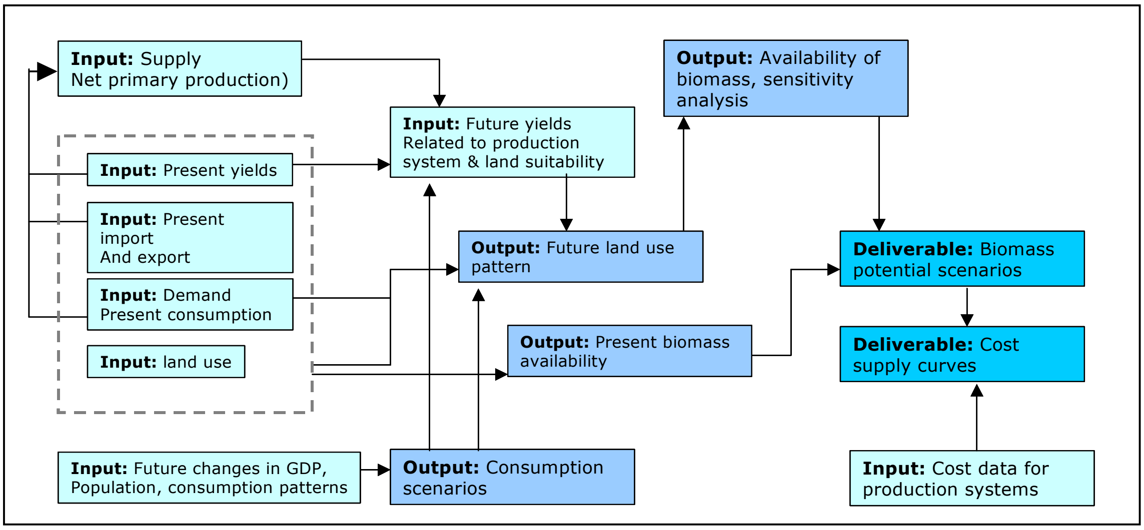


Figure 13: General overview of the main components of the methodology for biomass potential assessments

The total available biomass potential in a Nuts[13]-3 region is calculated as the sum of biomass from wood of surplus production forest, agricultural and forest residues and energy crops. The regional biomass potential assessment is based on land-use changes over time for a set of five scenarios that are briefly described in Table 2. The main characteristics of the different scenarios are:

- The agricultural production intensities; four types of crop production systems and productivity levels were defined: 1) Current agricultural production system (reflects the current agricultural production system in the CEEC), 2) Ecological production system, 3) High-input production system (optimum management practices, intensive farming with input on a level that guarantees maximal yield), 4) High-input advanced production system (similar to 3, but using most advanced technology and varieties).
- The allocation of food and feed production on Nuts-2, Nuts-3 or CEEC levels.

Information about the future demand for food and forest products was taken from FAO (Boedeker 2003) and UN-ECE Timber Section (Kangas and Baudin 2004). To cover the demand for food and forest products, a certain area of agricultural land and forest land will be needed. The size of this area will depend on 1) demand and 2) the defined production system (productivity).

[13] Nuts stand for "Nomenclature of Territorial Units for Statistics "and are the statistical regions of Europe and the Accession Countries (EUROSTAT 2002).

The currently available land minus the required future land for crop, livestock and wood production gives the possible surplus available land for biomass production, which can be used for energy crop cultivation. The biomass from energy crops is calculated by multiplying the available land for the energy crops with the productivity data for energy crops. The available land for energy crops depends on three factors:

Table 2: Selected parameters of the five scenarios that were used for biomass potential and cost analysis

Scenario	V1	V2	V3	V4	V5
Name	Full trade / High Tech	Current	CAP reforms	Protected Europe / High tech	Ecological
Story line	Full international trade, free market	CEEC lacks behind WEC in agricultural and economic development	CAP reforms are implemented	Highly protected Europe (closed market)	Ecologically oriented Europe
Agricultural Production system (FCE = feed conversion efficiency)	High input advanced technology, FCE based on WEC 2030	Current production system, FCE based on CEEC current situation	High input, FCE based on OECD 2030	High input advanced technology, FCE based on WEC 2030	Ecological (intermediate) input system, FCE based on current situation
Allocation	CEEC, division over countries	Country, division over Nuts-2	Country, division over Nuts-2	Country, division over Nuts-3	Country, division over Nuts-2

- The surplus total available land for energy crop production when food and wood production are fulfilled;
- The total area of suitable land for the selected energy crop;
- The remaining area of suitable land for the selected energy crop after fulfilling the individually required crop production (not valid for non-food energy crops).

Yield data for food, feed and biomass crops were received form IIASA for five land suitability classes (very suitable to not suitable; see Table 2) on 50x50 km grid-cell level. Biomass potentials and production costs are calculated for the years 2015 and 2030.

6.3 Results

Three categories of results are produced: the availability of land for energy crop production, the biomass potential in the CEEC and the cost-supply curves.

6.3.1 Available land for energy crop production in CEEC

The results show that in the V1, V3 and V4 scenarios, most land for energy crop production is generally available (see Table 3). There is not only a differentiation in the quantity of available land for energy crop production per scenario, but also in the quality of land that is available. Much (and good-quality) land is available under scenarios with advanced production systems, high agricultural productivity and good feed conversion efficiency, because under these scenarios less land is needed to cover the food and feed demand. Generally, the allocation of land on a higher level (see V1 scenario with allocation on CEEC level) contributes to higher availability of land for energy crop production because the optimal allocation of crops leads to higher yields per area unit and therefore less area demand for food and feed production.

Table 3: Land available for the production of energy crops in all CEEC under different scenarios

Scenario	**V1**	**V2**	**V3**	**V4**	**V5**
	In 1,000,000 ha				
VS land	18.7	4.4	16.6	19.1	5.8
S land	17.2	16.0	17.7	17.3	16.4
MS land	6.7	8.6	7.0	7.1	9.9
mMS land	1.9	5.6	1.9	2.0	5.4
Sum	**44.5**	**34.6**	**43.2**	**45.5**	**37.5**

VS = Very Suitable land, S = Suitable land, MS = Moderately Suitable land, mMS = marginally suitable land, NS = Not Suitable land)

6.3.2 Biomass production potential in CEEC

The total biomass production potential is the sum of agricultural residues, biomass derived from energy crops, forest residues and surplus forest land. Table 4 shows the results of the biomass potential in EJ for the sum of the CEEC for different scenarios. Poland contributes around 29%, Romania 24% and Bulgaria 12% of these biomass sources.

As a reference to the potentials, the results can be compared with the current final energy consumption for the countries of the CEEC, which is 6 EJ (year 2000, (DG TREN 2003)). Poland is the largest energy consumer among these countries, using 38% of the 6 EJ, which is a final energy consumption of 2.33 EJ (DG TREN 2003).

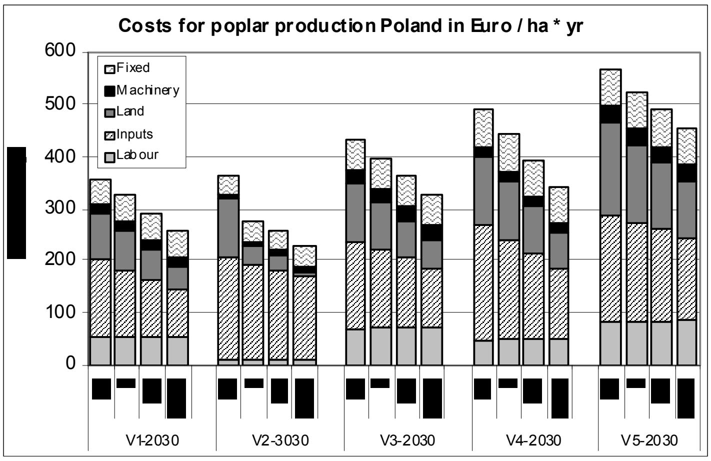
Table 4: Biomass potential (in EJ) from energy crops, agricultural residues, forest residues and surplus forest for the sum of all Central and Eastern European Countries

Selected energy crop in scenario	**Scenarios VIEWLS**				
	V1 2030	**V2 2030**	**V3 2030**	**V4 2030**	**V5 2030**
Willow	11.65	4.86	8.65	10.67	5.47
Poplar	10.27	4.35	7.63	9.25	4.85
Miscanthus	10.93	5.71	9.08	10.03	6.28
Conventional crops					
Rapeseed (grain)	4.39	1.22	3.33	3.31	1.27
Sunflower (whole crop)	5.95	3.46	5.24	4.97	3.49
Sugar beet (beet)	8.32	3.55	6.42	7.27	3.59
Potato (beet)	6.06	2.03	4.65	4.94	2.06
Sweet Sorghum (whole crop)	7.20	2.56	5.81	6.64	2.94

The perennial lignocellulosic crops (willow, poplar and miscanthus) generally show the highest potential in the CEEC. Of these, willow gives the best results, although sugar beet and rapeseed also show good potential. Differences in crop performances come from the availability of good-quality land for the crops and the yield potentials of the crops. For willow, for example, high amounts of good quality land are available in the CEEC, but for the energy crop sweet sorghum suitable land is only found in the most southern regions of the CEEC and therefore the biomass potential calculated for this crop is comparatively low.

If the selected energy crop is willow, the share of residues is 1% (V4) to 14 % (V3) of the total biomass potential; forest wood has a share of 1% (V5) to 5% (V4); energy crops hold for the biggest share of 83% (V3) to 94% (V5).

6.3.3 Production costs



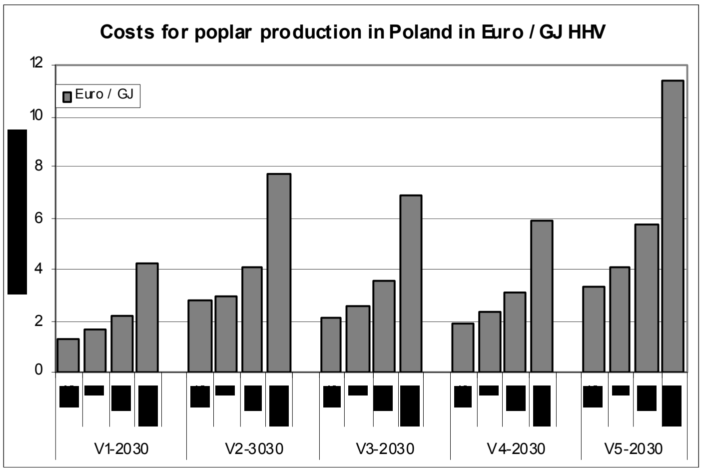
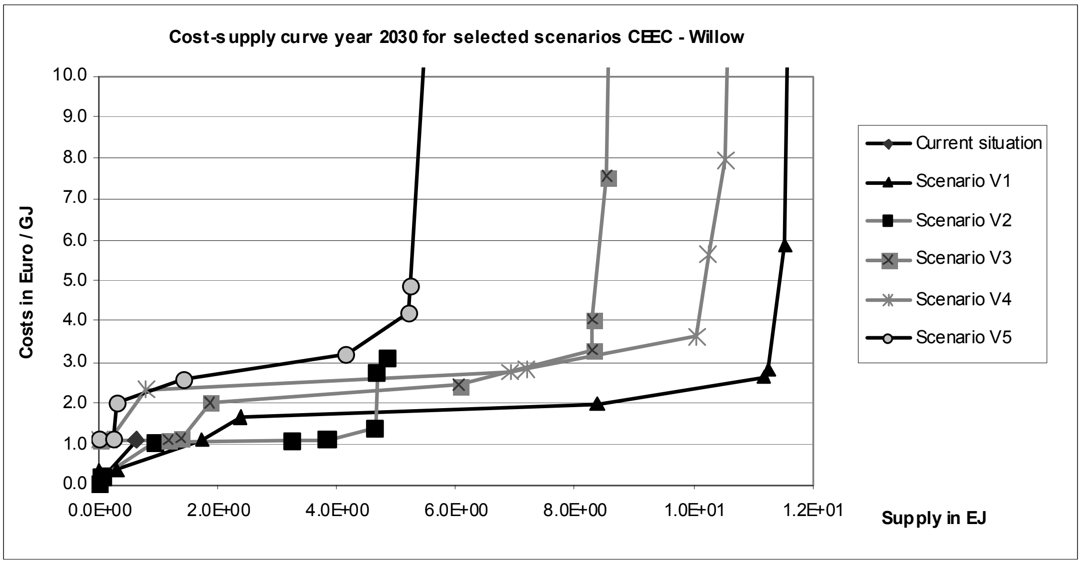


*Figure 14 (top): Total production costs, differentiated to cost items, in Poland for poplar production in €/ha * yr for different scenarios and land suitability types.*

Figure 15: Total production costs for poplar in Poland on country level in €/GJ HHV for different scenarios and land suitability types.



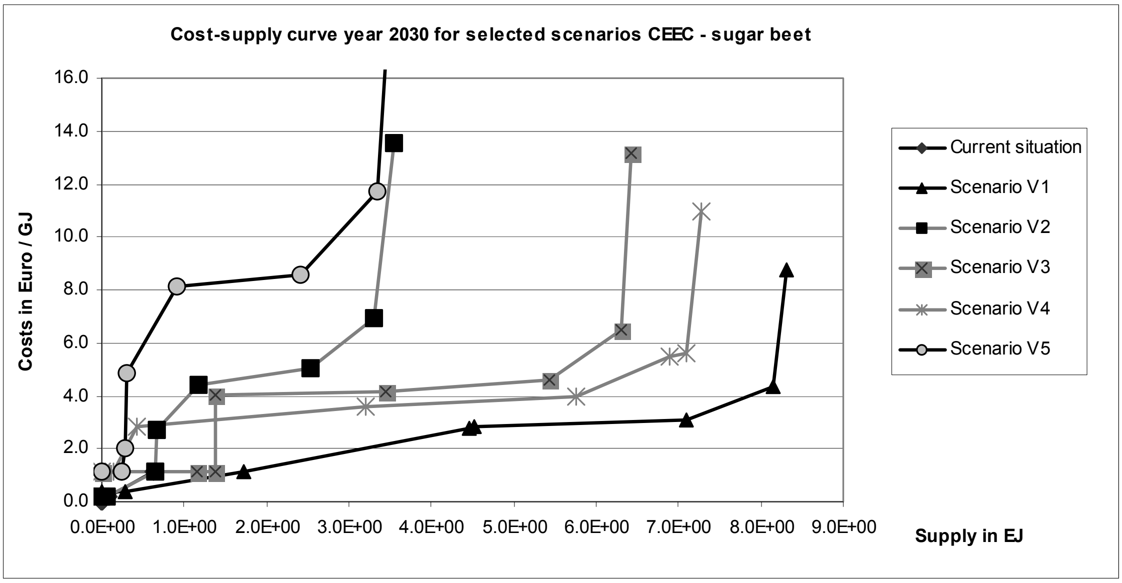


Figure 16: Cost-supply curves for all CEEC countries, based on willow (above) and sugar beet (below) as selected energy crops. Cost levels are average production costs, based on the % of available potential per individual CEEC country.

Residues are the cheapest; energy crops produced on land with low suitability are the most expensive source of biomass. The total biomass production costs per hectare decrease with decreasing land suitability. But the biomass production costs per ton biomass or GJ increase with a decrease in land suitability because less yield is harvested from low-quality land (see figure 14).

The biomass production costs vary in different scenarios, for different crops and in different regions. The main reason for cost variations between scenarios is differences in labour, land-use costs and input costs in different scenarios. The scenario V5, for example, with ecological production systems, is characterised by low productivity. This leads to a high demand for land for food and feed production and high land-use costs on the one hand and low yields of energy crops on the other hand, both factors leading to higher biomass production costs. Regional differences in biomass production costs occur through regional differences in land-use, labour costs and biomass yield potential.

Figure 15 shows the biomass cost-supply curve for the entire CEEC. In the current situation residues and wood from forestry are the only biomass sources available. In 2030, large biomass resources at prices lower than 3 or 2 Euro/GJ could become available from the energy crop willow.

6.4 Conclusions

The biomass potential in the CEEC region is dominated by the potential from energy crops and therefore strongly depends on the amount of land that is available for their production. The availability of land for the production of energy crops depends on the land demand for food production. Advanced, highly productive agricultural production systems and optimal allocation of crop production all over CEEC produces the most efficient land-use, and large areas of good quality land become available for the production of biomass.

Future agricultural production in CEEC will rationalise and agricultural land will become free. The results of the analysis carried out here not only show the high biomass potential in the CEEC, but also the possibilities for production alternatives on the large agricultural areas that are likely to become available in the CEEC in the near future due to ongoing changes in agricultural production and production methods in those countries.

There is a conflict between the extension of ecological agriculture and large-scale biomass production, mainly because of the low productivity of ecological agriculture. Supporting productive agricultural management systems, with the optimal use of agricultural inputs, modern varieties and efficient technologies, will also support the options of large-scale biomass production.

The countries with the largest land areas, Poland and Romania, clearly have the highest biomass potential, followed by Bulgaria and Hungary. Also on a Nuts-3 regional level there is a clear correlation between the amount of arable land and the potential for biomass production. Apart from large land areas, other favourable eco-physiological production conditions, such as fertile soils, can characterise a region with high biomass potential. This is not only true in terms of potential, but also for costs. The results of the cost analysis undertaken here show that biomass production costs (per ton or GJ) decrease with increasing land quality because higher yields can be obtained from better land. Therefore regions with good-quality land, that are currently often important agricultural production areas (e.g. PL03 or R003), can in future also become important biomass production areas. Another characteristic for a region with a high biomass potential can be the performance of extensive farming over large areas (e.g. in the region CZ03). In these regions large areas of agricultural land can become available through the intensification and rationalisation of agriculture.

The bulk of the biomass in CEEC could be produced at costs that are under 2 Euro/GJ and are therefore cheaper than fossil oil. High potential for bioenergy production and its competitiveness with bioenergy produced in Western European countries (WEC) or fossil fuels indicate a significant biomass/biofuel export potential for CEEC.

The costs for biomass production depend on the kind of energy crop chosen. Perennial lignocellulosic biomass crops have – in the order of willow, poplar, and miscanthus - the lowest biomass production costs, followed by sugar beet and rapeseed. The production costs for willow and sugar beet range in the order of 200 – 550 and 700 – 1200 Euro/ha*yr, respectively. This indicates that low subsidy levels can easily support energy crops in the transition phase.

The comparison of different energy crops under different scenarios clearly showed that the production of perennial lignocellulosic crop is to be given preference when high biomass potential, low biomass production costs and environmentally benign production methods are to be combined.

Although there is also a high potential for the production of sugar beet and rapeseed, note that these crops have higher demands towards land quality, requiring high, to very high, input intensities (especially pesticides) and can lead to soil erosion.

The bulk of the biomass potential (83 – 94%, depending on scenario chosen) comes from energy crops. To realise the high biomass production potential large areas of land, in the most extreme case i.e. up to 78% of the current agricultural area or up to 43% of the total land area, could be used for the production of energy crops, while at the same time food demand is met and forest and nature areas are preserved. The introduction of these alternative crops and the development of new markets will have major socioeconomic implications for the CEEC with positive effects on employment options and the development of the agricultural sector and rural areas.

The potential analysis showed that, under a scenario with intensive, advanced agricultural production methods and optimal land allocation within CEEC, nearly 12 EJ could be produced from biomass in the CEEC. In most of the CEEC, the production potential is greater than the current energy use in the more favourable scenarios (such as V1). Combined with the low cost levels, this gives CEEC major export opportunities for the European and perhaps global markets.

The VIEWLS project did not study the biomass production potential in Western Europe in detail, and no data are available for the different scenarios applied here to the CEEC. But an estimated 5-10 EJ of biomass (mainly from forest residues and wastes) may be available in Western Europe (or the old EU-15) and be added to the potential in CEEC. In total this is close to around one-third of the EU's energy use and larger than the current total oil imports of the EU. This order of magnitude figure makes it clear that biomass (and especially actively produced biomass from surplus agricultural land) could be a major alternative to fossil fuels in the coming decades and provides a key alternative to oil imports, since biomass is well suited to the production of transport fuels. The figures for CEEC also indicate that the indicative targets on biofuels and bioelectricity for 2020 can indeed be met, provided that coherent policy actions are taken, particularly with respect to developing perennial crop production in CEEC.

Some key recommendations are therefore:

- Develop an international biomass market allowing for international trade. Proper standardisation and certification procedures are to be developed and implemented on at least an EU, but preferably on a global, level.
- Ensure, in policy terms, that bioenergy is considered an integral part of energy, agriculture and forestry, waste and industrial policies. Such a holistic approach to biomass is much needed, to avoid future conflicting developments and to maximise the benefits of bioenergy deployment.
- Involve European agriculture in building bioenergy production capacity. In particular the development and deployment of perennial crops and their potential in CEEC's is of key importance for bioenergy in the long run. The EU's Common Agricultural Policy (CAP) should fully incorporate bioenergy, and perennial crops in particular.
- Specific regional (but also bi- or multilateral) efforts are needed to deploy biomass production and supply systems adopted for local conditions, e.g. typical for specific agricultural, climatic zones and socioeconomic conditions.

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7 Work Package 4 Possibilities and performance of international biofuel trade from CEEC to WEC[14]

7.1 Introduction

Work Package 3 (WP3) analysed the technical biomass production potential for the Central and Eastern European countries (CEEC). The results show, especially for scenarios with high input, the CEEC have advanced agricultural production systems, a substantial biomass production potential that in some scenarios even exceeds the current final energy consumption on a country level. When using this biomass potential, the CEEC can contribute significantly to meeting the set EU targets and to increasing the use of RES in total energy consumption. At the same time, a major new market – with potentially large positive influence on total bioenergy production and use in Europe – would emerge and rural development in the CEEC would be stimulated.

Thus, based on the results from WP3, it can be concluded that the CEEC have large amounts of available and under-utilised biomass resources. On the other hand, EU countries are deploying biomass in their energy mix, which cannot be met by their own indigenous biomass resources. However, a reliable supply of biomass and a reliable demand for bioenergy is vital to develop stable market activities, aimed at the bioenergy trade. International biomass trading can match supply to demand; in this case between Western European countries (WEC) and the CEEC.

Key to the development of large-scale energy crop production, infrastructure and capacity is the question to what extent the trading of biomass crops can contribute to cost reduction of producing energy carriers from biomass. Setting up infrastructures for large-scale biomass production will only occur when this becomes profitable for stakeholders in both the WEC and CEEC. Therefore, an important question is whether the market for biofuels and trade is profitable enough to realise the supply of biofuels from the CEEC to the European market.

International trade can include direct transport of biomass materials, intermediate energy carriers or high-quality energy carriers as fuels. Beside this, factors such as the biomass production method, the transport type and the order and choice of pre-treatment operations are of importance in the chain performance. Earlier examples of Hamelinck et al. (2003) have shown that intercontinental trade of biofuels and even bulk transport can be economically feasible.

[14] The activities in this work package have been implemented by Jinke van Dam, Andre Faaij, Iris Lewandoswki (Utrecht University, Copernicus Institute for Sustainable Development, Department of Science, Technology and Society, The Netherlands), Bruno van Zeebroeck (Transport and Mobility Leuven, Leuven, Belgium), Daniela Thrän, Doris Falkenberg, Michaele Hein, Gerd Schröder, Michael Weber (IE - Institute for Energy and Environment, Leipzig, Germany).

The main objectives of this study were therefore to:

- Define the critical factors to set up a stable international biofuel trade between CEEC and WEC.
- Estimate the cost performance of the energy carriers delivered in the WEC from the CEEC.
- Analyse the regional differences in cost performance of the energy carriers in the CEEC.

7.2 Methodology

Based on the results of regional biomass potentials in WP3, five Nuts-2 regions were chosen, which look promising for large-scale biomass production at low costs. Figure 17 shows the biomass potential (sum of biomass from energy crops, agricultural residues, forest residues and surplus forest) for a range of scenarios analysed in WP3.

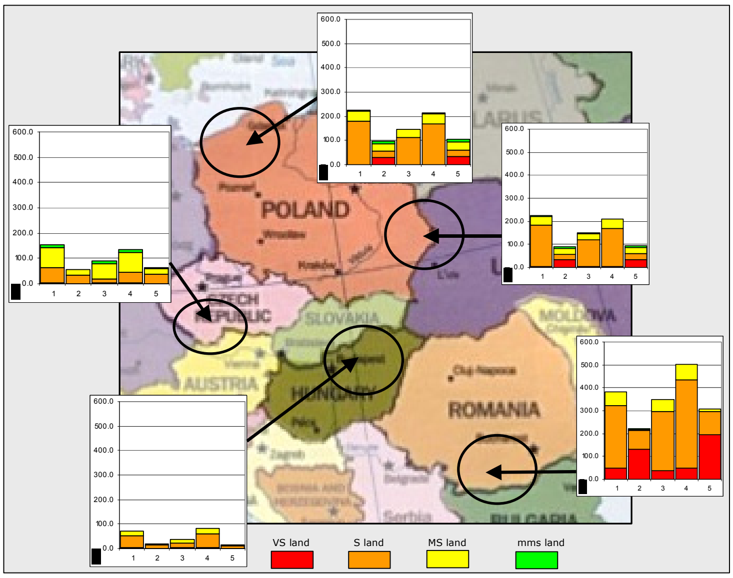

Figure 17: Biomass potential from energy crop willow (in PJ) in the selected regions for scenarios 1) V1 2030, 2) V2 2030, 3) V3 2030, 4) V4 2030 and 5) V5 2030 (explanation of scenarios see WP3). Selected regions are PLOG (NW of Poland), PLO3 (East of Poland), RO03 (Romania), HU05 (Hungary) and CZ03 (Czech Republic).

The biomass distribution densities in the region and the costs for biomass production were calculated based on data from WP3. To assess the availability of biomass in the region for large-scale export it was assumed that energy crops will produce 30% of the final current energy consumption in the region and biomass beyond that demand is available for export.

The modular spreadsheet model, developed by Hamelinck et al. (2003) was used for the technoeconomic analysis of the logistics of the long-distance chains for bioenergy

Based on information from Transport & Mobility Leuven (Belgium) international corridors to connect the biofuel destination areas with the selected biomass producing areas were identified (see Figure 18). For every region at least one option containing railway and one containing inland waterway shipping (IWW) or short-sea shipping (SSS) transport were identified (see Table 5).

Three biomass chains were analysed for every region:

- delivering pellets from willow biomass;
- delivering ethanol from willow biomass, ethanol conversion takes place in biofuel destination area;
- delivering ethanol from willow biomass, ethanol conversion takes place in regions of small-scale biomass production.

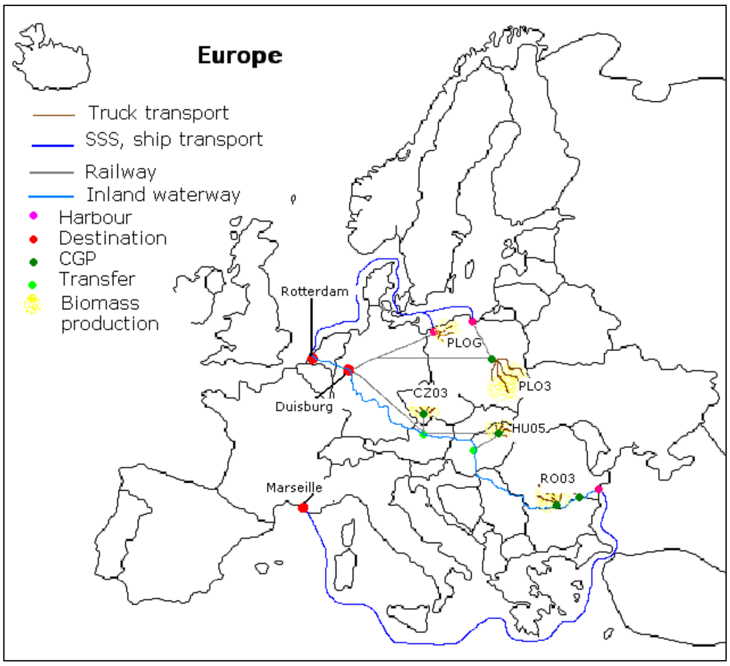

Figure 18: Main international transport corridors to connect destination areas with selected regions

Table 5: International transport routes and their distances for two transport corridors per region (CGP = Central Gathering Point).

Region	Option	Process	Location source	Destination	Distance in km.
PLOG	Option 1	Transport, SSS	CGP Szczecin	Rotterdam	976
	Option 2	Transport, railway	CGP Szczecin	Duisburg	702
PLO3	Option 1	Transport, railway	CGP Warsaw	Gdansk	318
		Transport, SSS	Gdansk	Rotterdam	1226
	Option 2	Transport, railway	CGP Warsaw	Border Poland - Germany	407
		Transport, railway	Border Poland - Germany	Duisburg	656
RO03	Option 1	Transport, IWW	CGP Calarasi	Constanta, Romania	118
		Transport, SSS	Constanta	Marseille, France	2915
	Option 2	Transport, IWW	CGP Giurgiu, Romania	Border Romania - Hungary	857
		Transport, IWW	Border Romania - Hungary	Border Hungary - Austria	293
		Transport, IWW	Border Hungary - Austria	Border Austria - Germany	355
		Transport, IWW	Border Austria - Germany	Duisburg	675
HU05	Option 1	Transport, railway	CGP Miskolc, Hungary	Budapest, Hungary	185
		Transport, IWW	Budapest	Hungarian – Austrian border	216
		Transport, IWW	Hungarian – Austrian border	Austrian – German border	355
		Transport, IWW	Austrian – German border	Duisburg	675
	Option 2	Transport, railway	CGP Miskolc, Hungary	Hungarian – Austrian border	278
		Railway via Linz	Hungarian – Austrian border	Austrian – German border	368
		Transport, railway	Austrian – German border	Duisburg, Germany	736
CZ03	Option 1	Transport, railway	CGP Budweis	Czech – Austrian border	68
		Transport, railway	Czech – Austrian border	Linz, Austria	64
		Transport, IWW	Linz, Austria	Austrian – German border	90
		Transport, IWW	Austrian – German border	Duisburg	675
	Option 2	Transport, railway	CGP Budweis	Czech – Austrian border	68
		Railway via Linz	Czech – Austrian border	Austrian – German border	167
		Transport, railway	Austrian – German border	Duisburg	776

7.3 Results

The costs for pellets vary from 68 to 130 €/tonne (see Figure 19 on next page), with a share of 22 to 34 €/tonne for biomass production costs. The highest biomass production costs are found in CZ03. Transportation costs have a share of 33 to 87 €/tonne, with the lowest transportation costs for inland waterway shipping (IWW) and the highest cost for railway transport. The transportation costs increase with the distance between biomass production and biofuel destination area and are lowest for the short-sea shipping (SSS) of pellets between PLOG and Rotterdam and highest for railway transport between HU05 and Duisburg.

When ethanol conversion takes place at the destination areas in WEC, ethanol supply costs vary between 7.4 and 13.6 €/GJ. The share of biomass production costs varies from 2.3 to 3.2 €/GJ. Around 0.5 to 1.1 €/GJ are ethanol conversion costs, 2.0 to 8.4 €/GJ transportation costs. When ethanol conversion takes place at the region of biomass production the ethanol supply costs vary from 6.0 to 9.4 €/GJ. Because ethanol conversion takes place on a small scale, the conversion costs increase to 1.3 to 2.7 €/GJ, but because of lower transportation quantities, at the same time transportation costs fall to 1.7 to 3.0 €/GJ.

7.4 Conclusions

The potential analysis in WP3 showed that, under a scenario with intensive advanced agricultural production methods and optimal land allocation within CEEC, nearly 12 EJ could be produced from biomass in the CEEC. In most of the CEEC region, the production potential is greater than the current energy use in the more favourable scenarios. Combined with the low cost levels, this gives the CEEC major export opportunities for the European and perhaps global market.

Here five regions with high biomass production potential in Poland, Romania, Hungary and the Czech Republic were analysed for biofuel export options. Form these regions pellets made from willow can be provided at costs of 68 to 130 €/tonne. Ethanol can be provided at 7.4 to 13.6 €/GJ if the biomass conversion is performed at the destination areas in the WEC, or at 6.0 to 9.4 €/GJ if the biomass to ethanol conversion takes place (on a small scale) at the CEEC region where the biomass is produced. From these results it can be concluded that the lowest logistic costs can be achieved when larger scale biofuel production takes place within the CEEC region. However, the supply security and financial risks of such large, regional facilities should be carefully assessed.

Short-sea shipping shows most cost advantages for longer distance international transport compared to inland waterway shipping and railway. The energy use (and GHG emissions) amounts to around 10% of the primary inputs.

Logistic capacity for key transport corridors (Donau, short-sea shipping) seems sufficient for the foreseeable term. Some international rail corridors may be more critical. Long-term planning of rail and harbour capacity should include these potential biomass and biofuel flows.

The selection of the destination area influences the economic performance of the trade chain. The biofuel supply costs are the lower if the distances between the regions of biomass production and the destination areas are shorter. Regions in Romania and Poland show a better economic performance for long-distance trade of biomass production than the regions in Hungary and Czech Republic (‘landlocked’).

In the coming decades, biomass and biofuel production in key CEEC regions can supply (pre-treated) biomass and biofuels to the European market at cost levels that are sound and very attractive to current and expected diesel and petrol prices.

7.5 References

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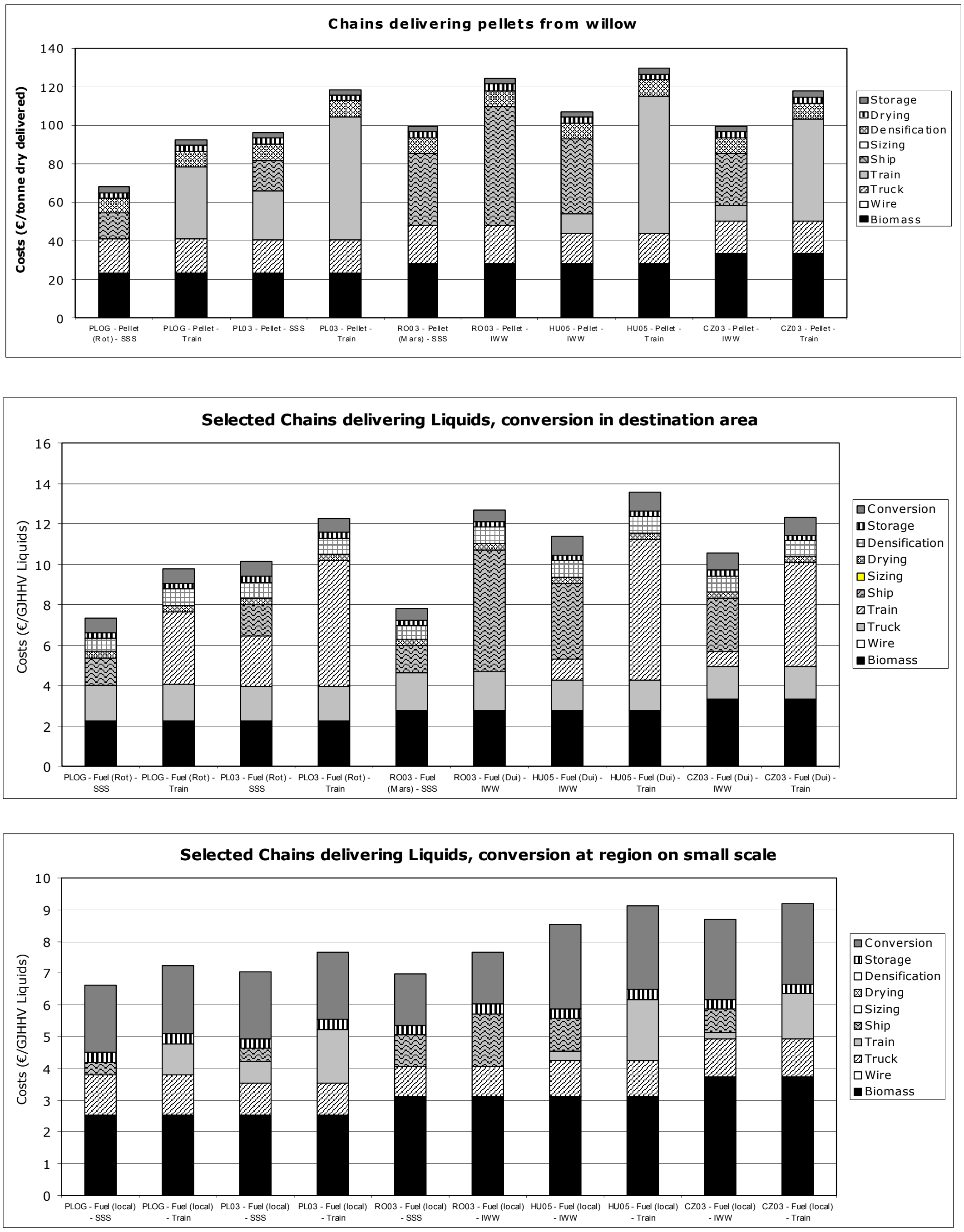

Figure 18: Costs for pellets in €/tonne dry delivered for selected logistic chains (fig. 18a). Costs for ethanol in €/GJ HHV for selected logistic chains. Ethanol conversion takes place in destination area (fig. 18b) or CEEC region where biomass is produced (fig 18c). Destination areas are Rotterdam – the Netherlands (Rot), Marseille - France (Mars) and Duisburg in Germany (Dui).

8 Work package 5 Biofuel and bioenergy implementation scenarios

8.1 Context and key questions

The objective of the activities in Work Package 5 of VIEWLS was to develop a cost-efficient biofuel strategy for Europe in terms of biofuel production, cost and trade, and to assess its larger impact on bioenergy markets and trade up to 2030. Based on the biomass availability and associated costs within EU-25, under different conditions, scenarios for biofuels production and cost can be constructed using quantitative modelling tools. Combining this with (cost) data on biofuel conversion technologies and transport of biomass and biofuels, the lowest cost biofuel supply chain given a certain demand that is predetermined by the Biofuels Directive can be designed. In a broader context, this is supplemented by a design of a sustainable bioenergy supply chain in view of the fact that biomass-heat, biomass-electricity and biofuels are competing for the same biomass resources. In other words, the scarcity of bioenergy crops, as manifested through overall bioenergy demand, is an essential variable in bioenergy scenarios.

Key questions that have been addressed are:

Under the European Biofuel Directive, which combinations of biomass options and biofuel conversion technologies constitute the short-term and long-term least-cost biofuel supply chain, taking into account all costs from biomass exploitation up to end-use conversion.

What biomass crop and/or biofuel trade flows will develop?

What will be the average end-user costs of realising biofuel targets?

What is the impact of biofuels on overall GHG emissions in the transport sector?

What is the potential for biomass production in CEEC countries, and what are the opportunities for bioenergy trade between CEEC and WEC countries?

What will be the dominant bioenergy sectors, i.e. heat, power, or transport, and is there synergy with the development of the biofuels supply chain?

What is the relative short-term and longer-term importance of biomass as an energy source, compared to conventional fossil and other renewable energy sources?

8.2 Methodology

In order to address the research questions mentioned above, a detailed analysis of the European biofuels market is combined with a broader analysis of the dynamics of the bioenergy sector, and the role of biofuels and bioenergy in the energy system as a whole. For this purpose, two complementary modelling tools have been used in this research, the BIOTRANS model and the ChalmersVIEWLS model.

The ECN BIOTRANS is a multi-commodity network flow model. Inputs for BIOTRANS are (1) regional costs and potentials of biomass resources from WP3, (2) technology parameters on conversion processes including technological learning, (3) transportation costs and (4) infrastructure and vehicle adaptation costs. The model was used to generate the lowest cost supply chain, from feedstock to end-use, for realising a specified demand for biofuels for the WEC and CEEC following the EU Biofuels Directive, with a target of 5.75% biofuels market share in 2010 - the scope of the Directive. It is assumed that the Directive is extended to a share of 20% in 2030. The transport segments that have been incorporated in the model in each country are: cars, buses and trucks. Given their characteristics, each biofuel replaces either petrol or diesel, in blended or pure form. BIOTRANS contains the conventional, state of the art as well as the more advanced biofuels. This also applies to the biomass input that includes, besides oil crops, residues etc., also higher energy density biomass such as lignocellulosic crops.

The ChalmersVIEWLS Model is a regionalised energy system model. It has three end-use sectors: electricity, transportation fuels, and heat (primarily heat/process heat and other energy use). Specific energy-demand scenarios are developed for each of the three sectors. In addition to energy demand and costs, the supply potentials, energy conversion characteristics and expansion limitations, the initial capital stock, trade parameters, CO_2 emissions for the included primary energy sources and related conversion/end use technologies, and also constraints set by policies are exogenously defined. This model was used to analyse issues relating to the production and energetic use of biomass (for heat, electricity and transport), focusing on a European level.

Whilst models can provide quantitative insights, they are still (and necessarily) abstractions from reality. For a complex field such as bioenergy this is no different. This means that in the methodology used, choices and simplifications had to be made. For biofuels, for which the BIOTRANS model was used, the focus has been primarily on cost, production capacities, trade, and on emissions, but not on other factors such as biofuel specifications, compliance with standards, end-use issues and non-economic factors such as public acceptance. For bioenergy, for which the ChalmersVIEWLS model was used, the focus has been on cost optimisation of the overall energy mix (consisting of biomass, renewables, and fossil sources) under a certain energy-demand scenario and assumptions on CO_2 emission limits and policies.

The ChalmersVIEWLS model is complementary to the BIOTRANS model, since the BIOTRANS model focuses on (and models in more detail) the transport sector, while the ChalmersVIEWLS model treats transport fuel choices in the context of total energy use. The model minimises the cost of meeting the European energy demand (including fuel demand for transport), which is defined on a country level, under varying predefined dynamic constraints regarding availability and cost of energy resources and technologies, plus other constraints such as carbon-abatement policies and other tools established to achieve the energy policy targets within EU.

8.3 Main results and findings

The objective of this research was to develop a cost-efficient biofuel strategy for Europe in terms of biofuel production, cost and trade, and to assess its larger impact on bioenergy markets and trade up to 2030. This entails the construction of a least-cost biofuels supply chain, in both the shorter and longer terms, to meet the demand following the EU Biofuels Directive, and the implications of this increased use of biofuels in terms of CO_2 emissions, fuel costs, and the allocation of biomass resources for biofuels and bioenergy purposes.

Although some sensitivity towards the various scenarios (see Chapter 5) has been found, the more important trends, predicted by the models in this research have been found to be fairly independent of the scenarios.

8.3.1 Biofuels for the short and long term

According to the models, it is the expectation that conventional biofuels, i.e. Pure Plant Oil (PPO) and biodiesel, followed by bioethanol, will have lower costs than future lignocellulose-based biofuels. However, from 2010 onwards the market share of conventional biofuels will gradually decrease in favour of future biofuels, such as lignocellulose-based bioethanol, FT-diesel and bio-DME. It is not clear, as this was not taken into account in the modelling work, to what extent the future fuel specifications, end-use issues and other aspects such as by-product markets will influence the total production costs and the practical application of conventional biofuels. Their costs will also increase as growing production volumes eventually leads to saturation of by-product markets (e.g. glycerol and animal feed) and consequently less by-products credits.

Since the CO_2 emission performance of future biofuels is much better than that of conventional biofuels (emission reduction compared to replaced fossil fuels 90% versus 45%), a structural cost stabilisation around conventional biofuels for a prolonged period, combined with a delay of the market penetration of future biofuels, would imply that more stringent climate targets e.g. under successful climate policies will be hard to meet.

Under current estimations about technological learning, the models predict rapid growth of advanced biofuels starting from 2010, in particular (but not exclusively) Bio-DME, Biomethanol and Compressed-SNG. Future advanced biofuels can have a break-even oil-price in 2010 in the range of 60 -100 USD/bbl if the technologies and the bioenergy crops can be developed to a sufficient scale.

In the distant future, typical 8 EUR/GJ projected costs of advanced biofuels can be achieved, providing that:

- the development and upscaling of advanced biofuel technologies, based for example on gasification, should be successful. Successful means: available on time, with sufficient production volume, product quality, and economies of scale.
- the cheap woody biomass potential in the CEEC becomes (and remains!) available at very low prices.
- advanced biofuels are able to meet stringent fuel specifications.

If these conditions are met, then biofuels will be able to compete with fossil fuels at a cost of around 7 EUR/GJ at an oil price of 40 USD/barrel[15]. This makes a high biofuels scenario a serious option for Europe in view of security of supply.

8.3.2 Biomass for biofuels

Based on the modelling results on the least-cost supply chain that meets the biofuel demand following the EU Biofuels Directive, the following conclusions can be drawn with respect to the development of biomass crops and biomass trade:

[15] Fossil fuel cost = oil price + 20%. 1 barrel oil = 5.74 GJ. 1 EUR = 1. 25 USD

Whilst energy crops will remain the dominant biomass for biofuels, residues and waste could increase after 2010 where the streams are available. This is because advanced technologies are more benign towards residues and waste.

Within the energy crop mix, lignocellulosic crops will grow at the expense of oil crops, which is the combined effect of the growth of future, more efficient technologies and the higher energy densities of lignocellulosic crops.

Under the Biofuels Directive, with an additional 20% target for 2030, there is sufficient biomass potential for biofuels in Europe, particularly in the CEEC, although some of the very cheap areas in the CEEC will become exhausted. This finding is independent of the degree of penetration of future biofuels compared to state-of-the-art biofuels, and is also independent of global scenarios for economic growth and sustainability. Transportation cost minimisation dictates that where energy crops are produced, biofuels are included as well, predominantly in the CEEC, though some in WEC.

8.3.3 Biomass for bioenergy

The increased use of biofuels as a result of the EU Biofuels Directive impacts the role of bioenergy in the overall energy system as well as the allocation of biomass resources towards various bioenergy applications. In this regard, the following conclusions can be drawn:

Under the condition of CO_2 emission restrictions, biomass demand in stationary applications (primarily heat, but also power) can help to boost early expansion of bioenergy, and in the absence of policies directing biomass to transport fuel production, stationary biomass uses remain the major demand source for bioenergy up to 2030. In the absence of such restrictions, coal is much more used in stationary applications and biomass is in fact preferably used for the production of transport fuels.

There appears to be sufficient biomass potential for biofuels in the EU, even under the high biofuels scenarios. At the same time, to also satisfy future bioenergy demand, including heat and power under a stringent climate scenario, biomass appears to become used to the maximum of its assessed technical potential. Energy crops will be high in demand since the potential waste and residue supplies will fall short of bioenergy demand.

Natural gas increases in all sectors, i.e. also in the transport sector where it becomes the major oil substitute by 2030 under the assumption that the Hydrogen Fuel Cell Vehicle does not become competitive and extensively used by that time.

The EU Biofuels Directive induces a redirection of biomass flows from stationary applications to biofuel production, leading to reduced average greenhouse gas reduction per unit of biomass use for energy.

Solid biomass is exported from CEEC to WEC to meet part of the WEC heat demand. WEC biofuel demand (arising from the Biofuel Directive) induces biomass production in the CEEC, with conversion to biofuels for export to WEC.

8.4 Recommendations

The modelling results indicate that present Directives and regulations affecting biofuels induce penetration of first-generation biofuels, such as PPO, biodiesel and bioethanol based on traditional starch-, sugar- and oil-based crops, on the EU markets. However, in the long term, biofuels that can be produced from more abundant and potentially much cheaper lignocellulosic feedstocks seem to be preferred. In addition, from the perspective of the total energy system, lignocellulosic crop production may also be preferred in the shorter term. Results indicate that from a cost- and climate-efficiency perspective, the use of solid biomass in stationary applications (especially heat) is the best option to cost-effectively initiate a biomass market for energy crops under stringent CO_2 emission restrictions. Biomass demand from the heat sector can be expected to stimulate lignocellulosic energy crop production and the establishment of a supply infrastructure leading to cost reductions along the biomass supply chain. In this way, it can bridge to prospective lignocellulose-based biofuel options, since the feedstock cost reductions will make those more competitive to their fossil alternatives.

For many European countries, especially CEEC, developing a biofuels market based on conventional biofuels may be attractive. The low costs of these fuels will lead to fast penetration in the transport fuel market. However, it is recommended that further development of lignocellulosic biofuels be stimulated, because of their higher CO_2 emission reduction potentials, their higher energy yield per hectare and their bridging function with other bioenergy applications. This can be achieved, among others, by establishing pilot-scale projects. These projects should involve pilot-scale advanced biofuel plants, in combination with pilot-scale lignocellulose crop production, in order to gain practical experience along the full supply chain, and to better understand the economic conditions under which bioenergy can come to fruition.

Due to the modelling methodologies used, some biofuels are more prominent in the research results than others. However, it is recommended to (continue to) stimulate market activities and investments aiming at further development of a broad range of biofuel options. As a result of local differences, such as production costs, that makes one biofuel option more attractive than the other, and it should be noted that conclusions regarding local situations cannot be drawn from the modelling analyses in this research.

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- IE – Institute for Energy and Environment, Germany
- Chalmers – Göteborg University (Chalmers University of Technology), Sweden
- ECBREC – EC Baltic Renewable Energy Center, Poland
- USAMBV – University of Agronomic Sciences and Veterinary Medicine Bucharest, Romania
- RILOG – Research Institute of Ornamental Gardening, Czech Republic
- HIAE – Hungarian Institute of Agricultural Engineering, Hungary
- ADEME – Environment and Energy Management Agency, France
- NTUA – National Technical University of Athens, Greece
- BLT – Federal Institute of Agricultural Engineering, Austria
- TML – Transport & Mobility Leuven, Belgium

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