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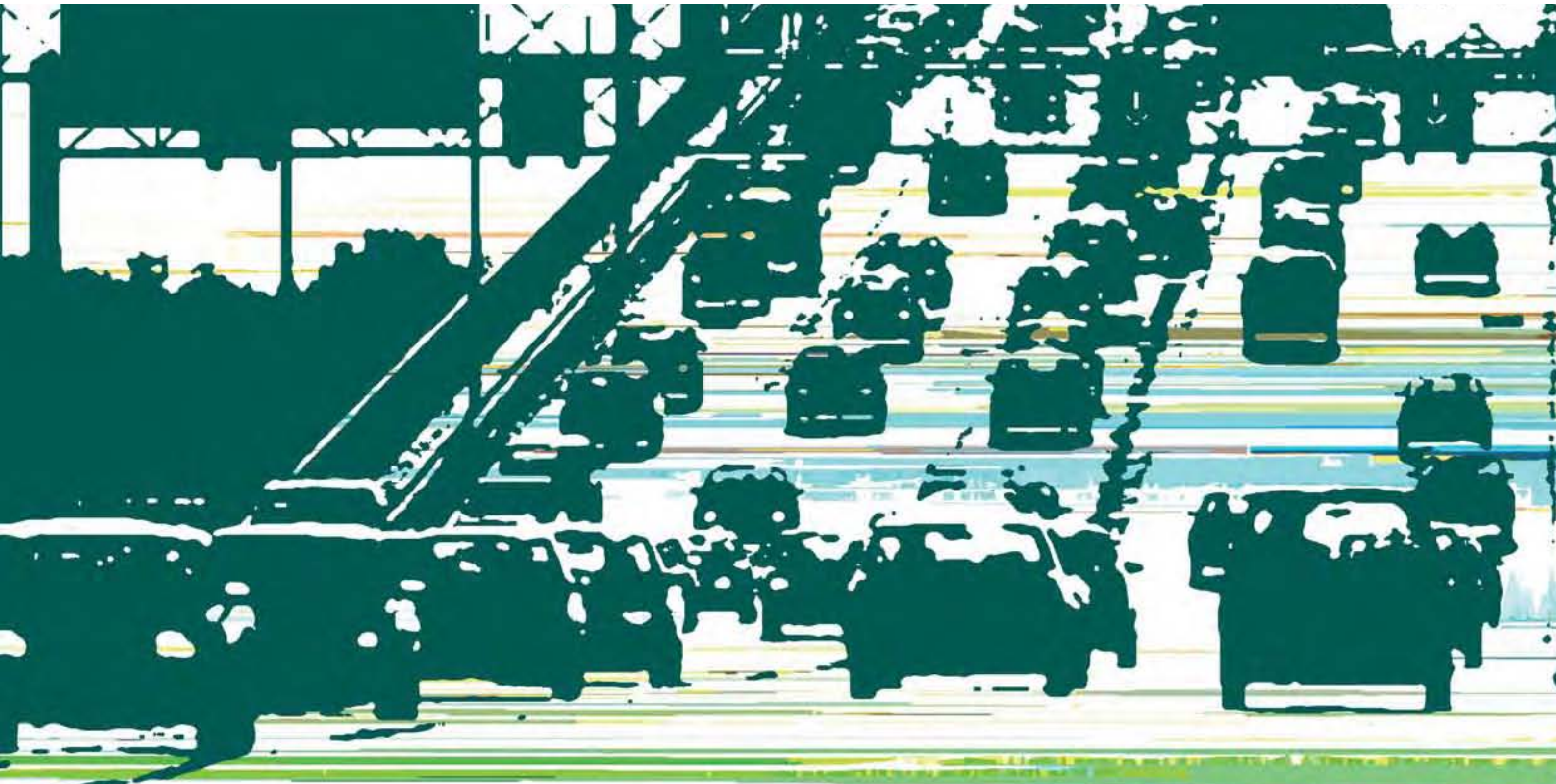

EUR 22066

Final report of the Biofuels Research Advisory Council

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Biofuels
in the European Union

A vision for 2030 and beyond

Final report of the Biofuels Research Advisory Council

2006

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EUR 22066

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Foreword

The European Union is strongly dependent on fossil fuels for its transport needs. In order to reduce this dependence and to meet our sustainability goals, we need a clean, secure and affordable supply of transportation fuels. There, biofuels can provide a very significant contribution in the short to medium term, and the Commission takes an active approach to promote the use of biofuels. For example, the Commission has recently adopted the Biomass Action Plan and the EU Strategy for Biofuels, and gives a high priority to research and development for biofuels and biofuel technology in the Framework Programmes for Research.

In an effort to better prioritise, co-ordinate and implement future research and development of biofuels, the Commission invited a group of high level experts representing widely different sectors of the biofuel chain. The mission of this group was to develop a foresight report – a vision for biofuels up to 2030 and beyond, which should address all the issues that are relevant to ensure a breakthrough of biofuels and increase their deployment in the EU.

The group, called the Biofuels Research Advisory Council (BIOFRAC), has described a vision for 2030. It is based on the members' past experience, current practice and future expectations. The vision does not mean to carve in stone a roadmap, or to elicit the setting of a target. Rather, it lays out the challenges ahead and suggests what it would take to meet them. Within this ambit, the vision report lays the foundations for a Strategic Research Agenda. It also recommends the creation of a European Technology Platform for Biofuels that will elaborate and implement this research agenda.

The vision report starts from the assumption that certain objectives can be met more effectively if pursued in a coordinated manner. This coordinated effort must fulfil a need that is broadly perceived by the sector at large – biomass producers, fuel producers, vehicle manufacturers and end users. It is in this context that the creation of a private-public partnership should bring about a research and development agenda that aims at technology development of value to both European industry and citizens.

I welcome BIOFRAC's recommendation to create a Technology Platform for Biofuels. I hope that its members will come together around a clear and unambiguous goal which will make it effective and will bring high added value to each of them.

I wish the platform a lot of success in embarking on its mission and in achieving its objectives.

Janez Potočnik
Commissioner for Science and Research

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Executive summary

Vision

By 2030, the European Union covers as much as one quarter of its road transport fuel needs by clean and CO_2-efficient biofuels. A substantial part is provided by a competitive European industry. This significantly decreases the EU fossil fuel import dependence. Biofuels are produced using sustainable and innovative technologies; these create opportunities for biomass providers, biofuel producers and the automotive industry.

The EU road transport sector accounts for more than 30% of the total energy consumption in the Community. It is 98% dependent on fossil fuels with a high share of imports and thus extremely vulnerable to oil market disturbance. The growing transport sector is considered to be one of the main reasons for the EU failing to meet the Kyoto targets. It is expected that 90% of the increase of CO_2 emissions between 1990 and 2010 will be attributable to transport.

Europe has defined ambitious targets for the development of biofuels. The aim is to improve European domestic energy security, improve the overall CO_2 balance and sustain European competitiveness. The development of innovative biofuel technologies will help to reach these objectives.

The current production of liquid biofuels in the EU 25 is about 2 Mtoe, which is less than 1% of the market. Although there have been marked increases in production and use in recent years, the market share is at risk of failing the EU policy target for 2010 of 18 Mtoe used in the transport sector.

The EU has a significant potential for the production of biofuels. It is estimated that between 4 and 18% of the total agricultural land in the EU would be needed to produce the amount of biofuels to reach the level of liquid fossil fuel replacement required for the transport sector in the Directive 2003/30/EC. Furthermore, biofuels can contribute to the EU's objectives of securing the EU fuel supply while improving the greenhouse gas balance and fostering the development of a competitive European (biofuels and other) industry.

An ambitious and achievable vision for 2030 is that up to one quarter of the EU's transport fuel needs could be met by clean and CO_2-efficient biofuels. A substantial part will be provided by a competitive European industry, using a wide range of biomass resources, based on sustainable and innovative technologies. Biofuel development will create opportunities for biomass providers, biofuel producers and the automotive industry. Also, the European technology will be used in 2030 in many countries exporting biofuels to Europe.

Reaching the vision means considerably increasing domestic biofuel production, while balancing it with international biofuel trade. This will not only require substantial investment in biomass production, harvesting, distribution and processing, but also calls for agreed biofuel and biofuel-blend standards.


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Biofuels will mostly be used in gasoline- and diesel-type internal combustion engines. However it is possible that specialised engines will be used in certain applications or in dedicated fleets. The majority of engines available in 2030 will require liquid fuels, although their molecular composition might have evolved from today's fuels. It will be beneficial if the new fuels are similar to, or at least compatible with, today's fuel types and specifications. Ability to mix fuels from alternative sources with current, conventional fuels without jeopardising the standard fuel specifications, and making use of existing infrastructure, is a very effective means for the implementation of these fuels.

Thus, the challenge is to increase substantially the production of biofuels that are commercially viable, CO_2-efficient and compatible with vehicle engines, by using innovative processes and technologies. To achieve this, it will be necessary, while supporting the implementation of currently available biofuels, to promote the transition towards "second generation biofuels", which will be produced from a wider range of feedstock (including waste biomass), reduce competition for land and food, and which will help to reduce costs of "saved" CO_2. To ensure the reduction of CO_2 emissions, a market mechanism will be required to ensure that CO_2-efficiency of bio-fuels is acknowledged and rewarded. Mechanisms (e.g. a certification scheme) could be used to promote the production and use of "more CO_2-effective" biofuels.

Research and development are paramount in reaching the vision. A phased development is envisaged based on short-term improvement of existing feedstock and technologies, RTD&D (research, technology development and demonstration) and commercial production of 2nd generation biofuels (mainly from lignocellulosic biomass), RTD&D and implementation of full-scale integrated biorefineries, and new energy crops.

For supply of the biomass feedstock, sustainable land strategies must be created that are compatible with the climatic, environmental and socio-economic conditions prevailing in each region. The production and use of both the primary and residual forms from agricultural, forestry and industrial operations should be promoted. Research on improving crop yields and energy input/output, as well as key quality characteristics using advanced technologies, should be taken carefully into account.

The expected growth of the biofuels market and the development of new transformation pathways make it timely to investigate new integrated refining schemes. The co-production of fuels, heat & power and co-products in integrated biorefineries will enhance the overall economy and competitiveness of biofuels. The biorefineries will be characterised by an efficient integration of various steps, from handling and processing of biomass, fermentation in bioreactors, chemical processing, to final recovery and purification of the product.


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There is a need for a well-co-ordinated strategy for the production of biofuels. As an important step, the recent Commission communication "An EU Strategy for Biofuels", supplemented by an Impact Assessment, describes seven policy axes which will regroup the measures the Commission will take to promote the production and use of biofuels. This Vision Report proposes the establishment of a European Technology Platform for Biofuels that should provide and help implement a strategy for biofuels, particularly in the transport sector. By so doing, and by making best use of EU knowledge and scientific excellence, the Technology Platform will contribute to the establishment and growth of a world-class, cost competitive European industry.

The purpose of the present document is to address all relevant issues and provide a vision and outline strategy, with emphasis on RTD&D, to increase, markedly, biofuels production and use in the EU. A good co-ordination between major European actors will be essential and would be facilitated by joint research and innovation programmes and joint operation of experimental facilities.
The Biofuels Technology Platform will provide the scenarios and strategic guidance for decision makers to set up the proper policy framework, and to help define and implement the strategic research needed to achieve the vision.

1 Introduction

The EU road transport sector accounts for more than 30% of the total energy consumption in the Community. It is 98% dependent on fossil fuels with the crude oil feedstock being largely imported and thus extremely vulnerable to oil market disturbance. The transport sector is considered to be one of the main reasons for the EU failing to meet the Kyoto targets. It is expected that 90% of the increase of CO_2 emissions between 1990 and 2010 will be attributable to transport.

Internal combustion engines will continue to be the dominant transport technology available in 2030, using mostly liquid fuels produced from both fossil and renewable sources. Biofuels provide the best option to replace a significant share of these fossil fuels.

Europe has defined ambitious targets for the development of biofuels. The aim is to improve European domestic energy security, improve the overall CO_2 balance and sustain European competitiveness. The development of innovative biofuel technologies will help to reach these objectives.

The EU has a significant potential for the production of biofuels. Biofuel use has to increase from its present low usage – less than 2% of overall fuel – to a substantial fraction of the transportation fuel consumption in Europe (in line with this report's vision of 25% in 2030). It is estimated that between 4 and 18% of the total agricultural land in the EU would be needed to produce the amount of biofuels to reach the level of liquid fossil fuel replacement required for the transport sector in the Directive 2003/30/EC.

Creating an EU market for biofuels will offer an opportunity for the new Member States that have more agricultural land per capita and will facilitate the absorption of the agricultural sector in the Common Agricultural Policy.

Biofuels production represents a major opportunity for the European economy. Developing innovative technologies can secure new jobs in rural areas, but also within industrial companies. In addition, new job opportunities could also arise from technology export. A study estimates that if the EU target for renewable energy in the European Union is met in 2010, the growth in net employment in the biofuels sector could be as high as 424 000 jobs with respect to the year 2000 (see Chapter 4).

Innovative technologies are needed to produce biofuels in an energy efficient way, from a wider range of biomass resources and to reduce costs. The options, which will be developed, need to be sustainable in economic, environmental and social terms, and bring the European industry to a leading position.

This means that apart from purely economic factors, e.g. investment, operating cost, and productive capacity, other factors have to be taken into account such as the greenhouse gas and energy balances, the potential competition with food production and the impact of biomass production on the environment.

The challenge therefore is to increase substantially the production of biofuels by using innovative feedstock, processes and technologies, which are both competitive and sustainable.

2 Actual situation

Policy context

Two of the main energy policy targets of the EU are to increase – by 2010 – the share of the Renewable Energy Sources (RES) in gross inland consumption to 12% and the share of biofuels in the market to 5.75% by energy content. For the transport sector in particular, the EU is supporting biofuels with the objectives of reducing greenhouse gas emissions, sustaining European competitiveness and diversifying fuel supply sources by developing long-term replacements for fossil fuels.

Recent assessments have concluded that the 2010 targets are unlikely to be achieved, and further efforts are needed. In 2003, total biomass use for energy purposes was 69 Mtoe. For the biomass sector in particular, to achieve the 2010 RES 12% target, 74 Mtoe more are needed by 2010, with the split between sectors as follows: electricity 32 Mtoe, heat 24 Mtoe, and biofuels 18 Mtoe. Total biomass use for energy would therefore be 130 Mtoe in 2010. This additional biomass production can only be achieved in the short term with targeted measures and actions, and a better co-ordination of EU policies.

The Commission has therefore taken an ambitious and co-ordinated approach to promote the use of biomass and biofuels. The approach includes a Biomass Action Plan and an EU Strategy for Biofuels. In the Commission's judgement, the measures in the action plan could lead to an increase in biomass use to about 150 Mtoe in 2010 or soon after.

Energy supply and demand

Fuels from crude oil supply about 96% of the worldwide energy demand for transportation. Other forms of energy (coal, natural gas, alcohols, electric energy) only have a significant role at a local level or for specific transport applications [1].

The nearly total dependence on fuels from crude oil is clearly not ideal. Crude oil reserves are limited and unevenly distributed in the world, with the most important reserves in politically unstable regions. Real or anticipated distortions of crude oil supply have previously led to sharp increases in crude oil prices and led to economic uncertainty. Therefore, a diversification of primary energies for fuel production will be necessary, especially to energy forms that are either locally available or at least more evenly distributed than crude oil. All kinds of primary energy are being discussed for fuel production but, for environmental reasons, renewable forms of energy are of particular interest.

Global biofuels production

Biofuels production of 33 billion litres in 2004 is small compared to 1,200 billion litres of gasoline produced annually worldwide. Brazil has been the world's leader (and primary user) of fuel ethanol for more than 25 years, producing slightly less than half the world's total in 2004. All fuelling stations in Brazil sell bioethanol or gasohol, a 25% ethanol/75% gasoline blend (E25). The US is the world's second-largest consumer and producer of fuel ethanol. The growth of the US market is a

relatively recent trend; ethanol production capacity increased from 4 billion litres in 1996 to 14 billion litres in 2004. Other countries producing and using fuel ethanol include Australia, Canada, China, Columbia, Dominican Republic, France, Germany, India, Jamaica, Malawi, Poland, South Africa, Spain, Sweden, Thailand, and Zambia.

Total world production of biodiesel in 2004 was more than 2 billion litres, of which more than 90% was produced in the EU25. Growth has been most marked in Germany (where pure biodiesel (B100) enjoys a 100% fuel-tax exemption until August 2006), and the country now has over 1 500 fuelling stations selling B100. Other biodiesel producers and users are France and Italy, with lesser amounts produced and used in Austria, Belgium, Czech Republic, Denmark, Indonesia, Malaysia, and the United States.

EU25 energy demand

The EC study "EU 25 - Energy and transport outlook to 2030" (DG TREN, 2003) presents data on final energy demand by transport activity and fuel type. Between 2000 and 2030, energy demand for passenger transport will increase by 14%, whereas freight transport will increase by 74%.

Based on this growth, the study predicts a strong increase in the need for middle distillate fuels for transportation, diesel fuel mainly for road transport, and kerosene for aviation. The demand for diesel fuel is forecast to grow by 51% from 2000 to 2030, due to the strongly growing need for freight transport services and an increasing number of diesel passenger cars. Gasoline consumption, on the other hand, is expected to even shrink in the last decade of the time period. For kerosene, an increase of nearly 60% has to be expected. Policies for the development of biofuels have to take these anticipated developments in fuel demand into account.

Table 2.1 shows the predicted energy demand for the three main liquid fuels in the transport sector from 1990 to 2030.

	1990	2000	2010	2020	2030
Gasoline	132.1	129.8	142.1	145.4	141.6
Kerosene	29.2	45.1	53.0	63.3	72.0
Diesel oil	103.0	147.7	182.1	207.6	223.6
Total	264.3	322.6	377.2	416.3	437.2

Table 2.1: Final energy demand for transport (Mtoe) by fuel type

EU25 biofuels production

Liquid biofuels production in the EU 25 amounted to 2040 ktoe in 2004 or about 0.7% of the market. Biodiesel from rapeseed predominates with a production of around 1720 ktoe in 2004. Ethanol is mainly produced from wheat, and to a lesser extent sugar beet, in Spain, France and Sweden, with a total of around 320 ktoe tonnes in 2004. These two fuels are commonly referred as first generation biofuels.

Biodiesel and ethanol are mainly used blended with diesel or gasoline, respectively, in low proportions (max 5%). High proportion blends, e.g. ethanol used for adapted vehicles (Flexi Fuel), and pure forms are also available in some countries. Most ethanol is processed into ethyl tertiary butyl ether (ETBE) as an additive to gasoline. Other transport fuels are developed at currently low market volumes, e.g. biogas in Sweden or pure vegetable oil in Germany.

Figure 2.1 shows the growth in biofuel production in the EU since 1993. Notwithstanding the significant growth, the 2005 reference value of 2% has not been achieved. There is substantial variation in Member States' efforts; if all Member States achieve the targets they have set, biofuels will attain a share of 1.4% (Figure 2.2).

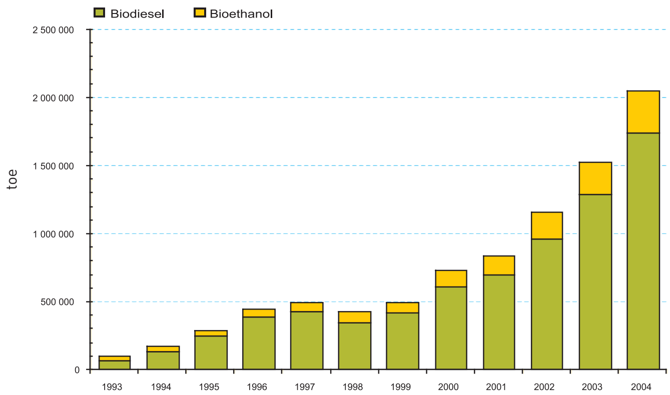

Figure 2.1: Biofuel production in the EU since 1993.
(2004: EU25). Source: Eurobserv'er 2005.

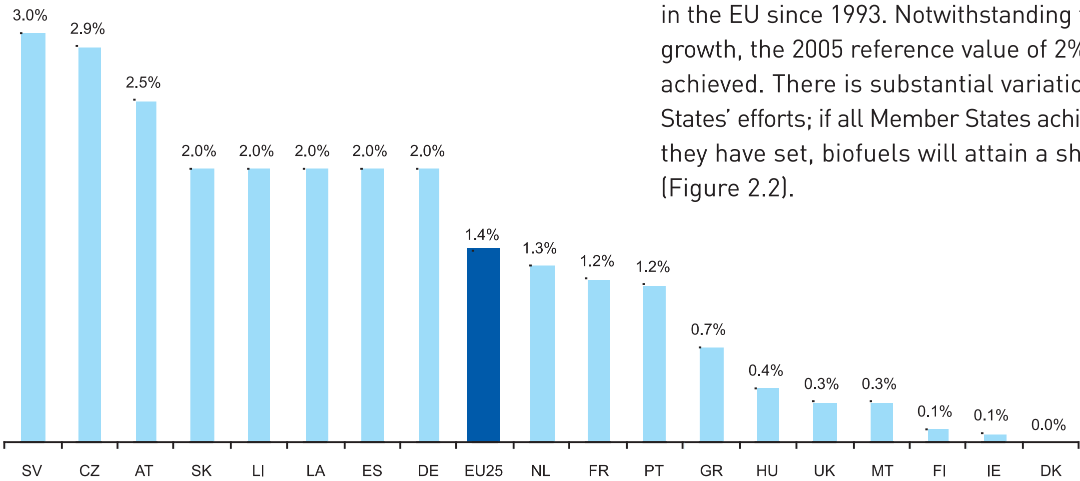

Figure 2.2: Biofuel targets for 2005 (EU25). Source: European Commission.

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Resource availability

Biomass resources comprise those based on agriculture or forestry, and other sources derived from agro- and wood industries, waste sources from construction and demolition, and municipal solid waste.

Based on a recent briefing of the European Environmental Agency [2],Table 2.2 gives an estimate of biomass potentials in the EU25 from 2010 to 2030. The ranges are based on data from different studies. The biomass resource potential till 2010 is estimated at more than 180 Mtoe. More than half is expected to derive from waste and residual forms of both agriculture and forestry origin. The remaining is expected to derive almost equally from wood and energy crops. The figures for 2020 and 2030 reach up to 239 and 316 Mtoe, respectively. Note that the figures illustrate only the energy content of the primary resource.

Resource type	Biomass consumption, 2003 (Mtoe)	Potential, 2010 (Mtoe)	Potential, 2020 (Mtoe)	Potential, 2030 (Mtoe)
Wood direct from forest (increment and residues)	67	43	39-45	39-72
Organic wastes, wood industry residues, agricultural and food processing residues, manure		100	100	102
Energy crops from agriculture	2	43-46	76-94	102-142
TOTAL	69	186-189	215-239	243-316

Table 2.2: EU25 biomass for energy production potential (figures illustrate only the energy content of the primary resource).
Sources: 2003 data from EUROSTAT; projections for 2010, 2020 and 2030 from European Environmental Agency [2].


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Biomass to biofuels conversion technologies

A strong knowledge and expertise exists in Europe in this area, both for biochemical and thermochemical systems.

Figure 2.4 summarises the main biomass conversion processes. The two pathways presently used in Europe at large scale are (i) ethanol production from sugar crops or starch (grain crops) and (ii) bio-diesel from oil-seed crops (rapeseed, sunflower, soy bean and other raw materials) converted into methyl esters (Fatty Acid Methyl Ester or FAME). Today, methanol, derived from fossil fuel, is used for the esterification. A better option in the future would be to use bio-methanol in the FAME production, or the production of Fatty Acid Ethyl Ester (FAEE) bio-ethanol instead of methanol.

Ethanol can be incorporated in the gasoline pool, either by direct blending (at present max. 5%, based on the current gasoline norm EN228) or by transformation, both without engine modifications. Some ethanol is also used as an 85% blend (E85) in flexible fuel cars, mixed with diesel using a stabilising additive (e-diesel) on test fleet level, and as fuel for diesel buses (with ignition improver). The most frequent use of ethanol in Europe at present is through conversion into ethyl tertiary butyl ether (ETBE) by etherification of ethanol and iso-butene, the latter being a by-product of refinery processes). ETBE, however, may have (like other ether-oxygenates) some disadvantages, such as potential ground water contamination. Its use is currently limited by the availability of isobutene.

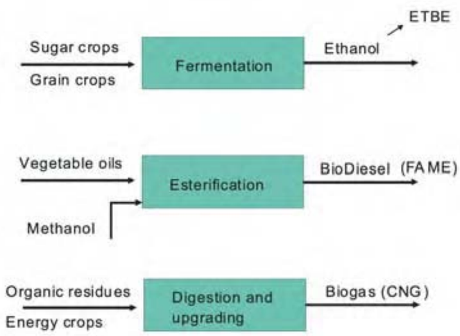

Figure 2.4: Present biomass transformation processes.

Pressed vegetable oil as such has been tested in vehicle fleets with mixed results. Conversion of oil of biological origin (plants/animals) by esterification with methanol results in a fuel widely accepted by diesel engine manufacturers. It is used both in pure form (in trucks) and admixed to diesel from mineral oil (at present 5%, based on the current diesel norm EN590). Esterification of oils from biological origin with bioethanol will be discussed further in order to generate biodiesel independent from fossil fuels.

The production of biogas is a third available pathway. It can be either produced in dedicated facilities from organic wastes or recovered from municipal solid waste landfills. The recovery of biogas is important not only as a resource, but also for avoiding the discharge of a greenhouse gas in the atmosphere. Upgraded biogas compressed at a pressure around 200 bar can be used as an engine fuel, but presently represents a niche market.

Table 2.3 provides an overview of biofuels and the feedstock and processes used in their production.

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First generation (conventional) biofuels			
Biofuel type	**Specific names**	**Biomass feedstock**	**Production process**
Bioethanol	Conventional bioethanol	Sugar beet, grains	Hydrolysis & fermentation
Vegetable oil	Pure plant oil (PPO)	Oil crops (e.g. rape seed)	Cold pressing/extraction
Biodiesel	Biodiesel from energy crops Rape seed methyl ester (RME), fatty acid methyl/ethyl ester (FAME/FAEE)	Oil crops (e.g. rape seed)	Cold pressing/extraction & transesterification
Biodiesel	Biodiesel from waste FAME/FAEE	Waste/cooking/frying oil/animal fat	Transesterification
Biogas	Upgraded biogas	(Wet) biomass	Digestion
Bio-ETBE		Bioethanol	Chemical synthesis
Second generation biofuels			
Biofuel type	**Specific names**	**Biomass feedstock**	**Production process**
Bioethanol	Cellulosic bioethanol	Lignocellulosic material	Advanced hydrolysis & fermentation
Synthetic biofuels	Biomass-to-liquids (BTL): Fischer-Tropsch (FT) diesel Synthetic (bio)diesel Biomethanol Heavier (mixed) alcohols Biodimethylether (Bio-DME)	Lignocellulosic material	Gasification & synthesis
Biodiesel	Hydro-treated biodiesel	Vegetable oils and animal fat	Hydro-treatment
Biogas	SNG (Synthetic Natural Gas)	Lignocellulosic material	Gasification & synthesis
Biohydrogen		Lignocellulosic material	Gasification & synthesis or Biological process

Table 2.3: Overview of biofuels and the feedstock and processes used in their production.

3 Challenges and opportunities for the future

Securing future mobility

Before determining the potential role that biofuels in EU 25 can play by 2030 and to recommend appropriate policies for the development of biofuels, it is important to assess the quantity and structure of future energy demand for transport, and the underlying data for mobility and economic growth. Chapter 2 presents data from the baseline scenario of a recent study by DG TREN [3].
The main points to note from the study are the following forecasts for the period from 2000 to 2030:

- For the EU 25, an average annual growth of 0.6% for primary energy (0.9 % for final energy), compared to 2.4 % increase for GDP;
- An increase in dependency on energy imports, from 47.1% in 2000 to 67.5% in 2030;
- Freight transport growing at an annual average of 2.1% for the EU 15 and 2.3% for the new member states. Road traffic will gain significantly in terms of market share, mainly at the expense of rail. In 2030, road traffic will account for 77.4% of freight transport services, compared to 69.0% in 2000;
- Personal transport growing at an annual average value of 1.5% in the EU 25, distinctly lower than the growth in GDP. The strongest increase is forecast for aviation, which will double its share to 10.8% and will account for 16% of the overall energy demand of the transport sector in 2030. However, private cars and motorcycles will by far remain the most important means for personal transport, with a market share of 75.8% in 2030, compared to 77.7% in 2000;
- The largest increase in fuel use for transport in absolute terms is expected to be for trucks and buses. After 2010 the fuel demand by trucks is forecast to even exceed that for passenger cars and motorcycles.

According to the above study, liquid hydrocarbon fuels will dominate the market by 2030, and diesel will increase its proportion at the expense of gasoline. As a result there would be a deficit of produced diesel compared to demand and an overcapacity of gasoline production in Europe. This imbalance is a risk to European supply security, but could also present a substantial opportunity to the European biodiesel industry. There will also be a need for kerosene, mainly for aviation.

User acceptance of biofuels is paramount. Ideally, users should not notice the difference between conventional and biofuels, nor should they be required to extensively modify their existing vehicles or perform new routines when using biofuels (although future vehicles will have to employ new technology).

Storage, distribution and sales logistics are also important issues. For the private motorist market (cars), it is a benefit if the biofuels are compatible with existing logistics systems. For commercial vehicles, particularly truck and bus fleets, separate (dedicated) fuel distribution systems are already common. For commercial vehicles, overall economics will largely dictate how the fuel distribution is organised. In any case, existing infrastructure investments will be in use for their full economical life-time, even with new fuels being introduced to the market.

It seems likely that large-scale biofuel penetration is only possible if the existing engine technologies can be utilised. Ideally, future biofuels could be used as blends to gasoline, diesel or natural gas, or as neat products. Also alternating between biofuels, conventional fuels and blends should be possible.

In the period to 2030 it is expected that the regulated exhaust gas emissions (NOx, CO, HC, particulates) will be further reduced in steps to reach near-zero emissions, with vehicle emissions stable over the vehicles life. High quality of the fuel is an important enabler to comply with stringent emission regulations. Emission standards (and other vehicle standards) should preferably be based on global technical regulations with relatively minor regional adaptations. Fuel quality must therefore be compatible with this reality on a global basis. In parallel, energy consumption / emission of greenhouse gases should be reduced significantly due to legislation, incentives and increased cost-effectiveness of the transportation means.

Reducing greenhouse gas emissions

Reducing greenhouse gases (in particular carbon dioxide) in the transport sector is one of the most important drivers to promote biofuels.

In a recent study by JRC/EUCAR/CONCAWE [4], different biofuels were compared in terms of both the economics (cost of avoided CO_2) and the potential for CO_2 emission reduction compared with a conventional fuel using crude oil at 50 €/barrel.

Figure 3.1 shows that, by moving from first generation to second generation biofuels, the fraction of avoided CO_2 can be increased whilst simultaneously reducing the cost of the avoided CO_2. Note that for indicating the most suitable fuel of the future, other factors have also to be taken into account.

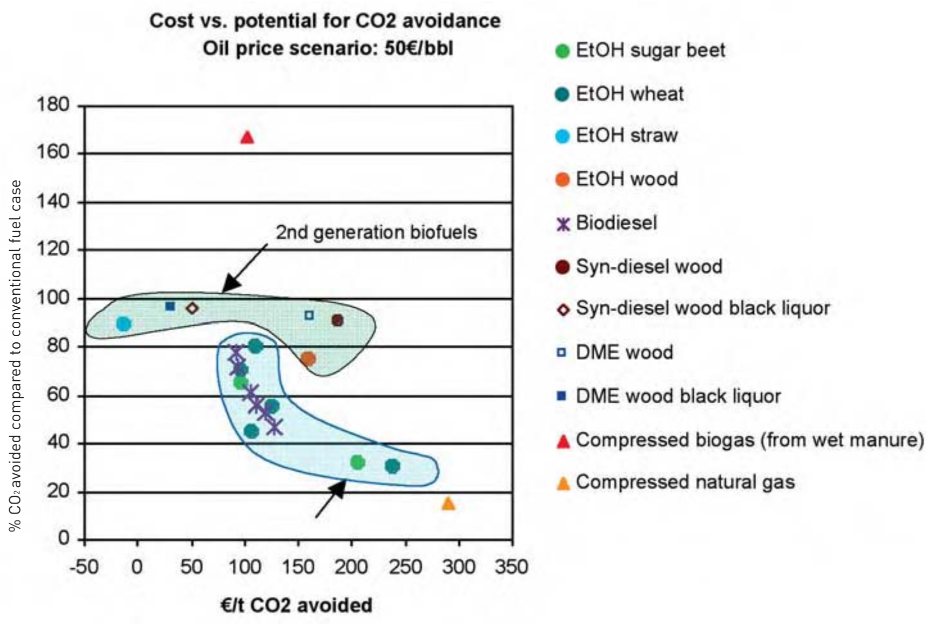

Figure 3.1: Indicative CO_2 reduction potential versus costs for CO_2 avoidance (source: WtW study, Eucar/Concawe 2005). Please note that the volumetric potential of the different fuel options is not taken into consideration. The higher than 100% CO_2 avoidance for biogas results from the reduction of methane emission through degradation of organic waste and manure in a controlled fermentation process where CO_2 is replacing methane (a much more powerful greenhouse gas).

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The challenge is to increase substantially the production of biofuels by using innovative processes and technologies that are both competitive and sustainable. To achieve this, it will be necessary, while supporting the implementation of currently available biofuels, to promote the transition towards second generation biofuels, which will be produced from a wider range of feedstock, do not compete with the food chain, and will help to reduce costs of "saved" CO_2.

Fuels from biomass, therefore, have a high potential to reduce greenhouse gas emissions, and hence are an important means to fulfil road transport CO_2 emissions targets. They can be a reliable fuel source, which can gradually reduce the dependence on oil imports, and, if further developed, can constitute part of a strategic reserve.

Notwithstanding the fact that biomass in electricity has the greatest greenhouse gas benefits and biomass in heating is cheapest, transport biofuels have the highest employment intensity and provide the only renewable alternative for existing vehicles. The use of biomass should be promoted in all three sectors. At least up to 2010, there will be no major competition for raw material: biofuels rely mainly on agricultural crops while electricity and heating rely mainly on wood and wastes.

Increasing biomass supply

Currently, agricultural and forestry systems exploit only part of their production, i.e. "primary" products, while they leave unexploited significant "residual" quantities. The use of both the primary and the residual resources through integrated and sustainable pathways should be promoted. It will also be necessary to utilise biomass fractions that are presently discarded and to make the best use of the whole plant. Specific non-food, high-yield biomass can be developed but needs to take account of issues, such as biodiversity and labour conditions. When non-European feedstock is used they need to meet the same sustainability criteria as in the EU.

The main challenges concerning biomass resources are:

- Supply the industry with secure raw material
  - Efficient land use by the use of whole-crop solutions and by exploiting both fertile and marginal land.
  - Ensure that both primary production and residues are evaluated for their energy potential.
  - Sustainability in biomass production- handling techniques.
- Improve the acceptability of the biomass sector by strengthening the communication channels among the relevant stakeholders, especially the farming and forestry sectors with the respective fuel and energy sectors.
- Balance domestic biomass production against international biomass trade.

Different sectors – food, feed, fibre, chemicals and energy – compete for biomass from agriculture and forestry. Therefore, biomass production for energy has to be as efficient as possible per unit area in order to minimise the competition for land.

Planning efforts should focus on choosing the best available cropping solutions for each region and land type. The suggested criteria for such an evaluation include: high energy and cost efficiency, adequate greenhouse gas savings, soil and water protection.

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Genetics can be used to improve the quality characteristics of the crop, e.g. decrease lignin content so that whole crop use becomes efficient.

It can be noted that there are 3 parallel paths in the biofuel industry development:

1. The first path is to use food-type feedstock such as wheat, vegetable oils...

2. The second path is to make biofuels out of the residues or waste of current agriculture or forestry and industry. This will increase the availability but rely on the development of robust development technologies (see above). The overall availability is limited by factors such as the concentration of the residues, or the amount of food-crop production (eg. straw and wheat). This option will develop between 2010 and 2020.

3. The third path is to use energy crops, i.e. biomass that is grown deliberately for biofuels applications (see below). The potential for energy crops can be massive (highly productive crop, possibly genetically modified, with a rational agriculture). This stage requires that bio-diversity and impact studies are carried out with a long lead time. Studies must start now for full implementation in 2020 and beyond.

Energy crops

Dedicated energy feedstock in the form of energy crops represents a promising solution to security of supply issues for future biofuel production. Like the other biomass resources, they can be converted into virtually any energy form. However, their main advantage is that they can be developed to optimise key characteristics for energy applications and their sustained production can better ensure long term large-scale supplies with uniform characteristics.

Energy crops may also have significantly higher yields per unit of land area than natural strands. These higher yields improve their cost effectiveness over conventional crops and minimise land requirements, associated chemical use, and haulage requirements.

Throughout Europe there are certain cases which exist mainly due to the political and financial support provided by member states such as oilseed crops for biodiesel in Germany and France, Short Rotation Coppice for heat in the UK and willow plantations for heat and electricity generation in Sweden.

Taking into account current agricultural systems as well as the respective legislative and political framework in the EU25 and individual member states, energy crops are expected to play an increasingly significant role as future biofuel resources, starting from existing oil, starch and sugar crops for the first generation of biofuels and progressing to high-yield and moderate-input lignocellulosic cropping solutions.

4 Vision for 2030 and beyond

A vision for biofuels

Up to one quarter of the EU's transport fuel needs can be met by clean and CO_2-efficient biofuels by 2030. A substantial part is to be provided by a competitive European industry with biofuel developments based on sustainable and innovative technologies creating opportunities for biomass providers, biofuel producers and the automotive industry. International trading of biofuels (components) will increase.

In 2030, biofuels will mostly be used in internal combustion engines, as these technologies will still prevail. However it is possible that specialised drivetrains, e.g. fuel cells, will be used in certain applications or in dedicated fleets.

Integrated biorefineries co-producing chemicals, biofuels and other forms of energy will be in full operation. The biorefineries will be characterised, at manufacturing scale, by an efficient integration of handling and processing of biomass, fermentation in bioreactors, chemical processing, and final recovery and purification of the product. Future installations will be much more flexible than the present ones, both in terms of feedstock and products. The level of sophistication and control, built up over many years in the chemical industry, shall thus have been achieved also in biorefineries. The development of biofuels requires a high degree of innovation and investment and is expected to boost rural economies and contribute to industrial growth.

The technical potential underpinning the vision

Preliminary results of a study by the European Environmental Agency [4] suggest "that there is sufficient biomass potential in the EU-25 to support ambitious renewable energy targets in an environmentally responsible way". According to this study, domestic raw biomass availability could range between 243 and 316 Mtoe in 2030 (see Chapter 2).

Starting from the low estimate, and taking a mean conversion factor of 40% using current technology, this would yield approximately 97 Mtoe of biofuels. Considering the high estimate, and assuming an optimised conversion factor of 55% using future technologies, the available raw biomass could yield up to 174 Mtoe biofuels.

In 2030, domestic EU biomass would thus hold the ***technical potential*** to cover between 27 and 48 % of our road transport fuel needs (360 Mtoe, see Chapter 2), if all biomass would be dedicated to biofuels production. Significant cost reductions in the production process would be needed to transform the technical potential into economic potential. Cost reduction of 20-30% seems plausible using future technology (beyond 2010 [5]).

Taking as a base case that half of the EU biofuel supply in 2030 could be covered by domestic production and the other half by imports, it seems realistic to aim at one quarter of the EU road transport fuel needs in 2030 being covered by biofuels.

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Considerations for reaching the vision

The one quarter of EU road transport fuel needs in 2030 mentioned above, and half of that produced domestically, would mean converting in the order of 100 million tonnes of biomass into biofuels.

Reaching the vision will therefore require substantial investment in biomass production, harvesting, distribution and processing. These investments in new technologies would give European industries the possibility of increasing and accelerating their expertise as compared to their global competitors, both for first and second generation biofuels. In a similar vein, the development of biorefineries could improve rural economies and contribute to industrial growth. This could provide positive benefits for Europe in the medium to long term. Clearly, a favourable political climate, providing the appropriate legislative and financial framework, is crucial for instigating this level of investment.

Reaching the vision will obviously bring a cost to society. Looking at the near future (2010), a regulated market-based approach that encourages the development of the EU's domestic biofuel industry in a balance with imports would bring an average cost of € 6 billion per year in order to meet the indicative target of the Biofuels Directive [6,7,8,9]. Relating this to the gross diesel and gasoline consumption in the EU25 (334 billion litres in 2002) yields an average increase of transport fuel cost of 1.2 to 2.5 euro cents per litre in order to finance the additional biofuel use targeted for 2010.

Increased use of biofuels will have ***direct*** and ***indirect*** employment effects. A study by the European Renewable Energy Council [10] estimates that meeting the EU target for renewable energy for 2010 will result in a growth in net employment in the biofuels sector of 424 000 jobs with respect to the year 2000. An ***indirect*** effect could be the multiplier opportunities which could increase the direct effect. On the other hand, jobs in the biofuel sector might replace other jobs, and the net employment effect could be much less. Impact Assessments [7,9] indicate that the above mentioned indirect effect on net employment could range between minus 40 000 to plus 15 000 jobs, depending on how wages and unemployment payments evolve with higher energy prices.

The uncertain development of oil prices and of the cost of biofuel production makes it difficult to quantify the cost to society of reaching the vision for 2030. Preliminary estimates in this Vision Report, based on 2005 market prices, suggest that 25% biofuels in road transport in 2030 could cost in excess of € 31 billion per year, equivalent to an additional 6.6 euro cent per litre of gasoline and 8.2 euro cents per litre of diesel.

In this context, the cost of increased biofuel use to society has to be weighed against the monetary value of the benefits, such as enhanced security of supply, reduced greenhouse gas emissions, diversification of our energy mix, and job creation in rural areas. A forward-looking biofuel strategy with a strong focus on research, development and innovation should be part of a consistent set of research and energy policies which have as their goal a cleaner and sustainable energy future.

5 Strategic Research Agenda

Figure 5.1 gives an overview of different routes from primary energies to fuel, with a special emphasis on the potential of biomass. The figure shows that diversification of primary energy does not necessarily mean a different kind of fuel than today. In general, fuel can be produced from a variety of feedstock, involves several production steps and uses intermediate products to generate the finished fuel (and other products). The same routes are possible for biomass as for fossil resources. Biomass can be liquefied to yield an intermediate "bio crude" (that can be further transformed in a petroleum refinery or gasified for syngas), or directly gasified for synthesis gas or SNG. Moreover, FAME, FAEE and other derivatives can be produced directly from oil containing plants, and ethanol from sugar, starch or, after pre-treatment, from cellulose.

Other renewable forms of energy are less flexible in that the only fuel product will be hydrogen produced using renewable electricity (although solar thermal energy can be used for the gasification of biomass). For nuclear energy, the situation is similar.

Hydrogen can be produced from a number of primary energy sources, including biomass, and used directly for vehicle propulsion. However, hydrogen requires far-reaching changes in technology and infrastructure. In particular, energy effective use of hydrogen requires the introduction of fuel cells instead of internal combustion engines and, therefore, adds another technology and cost challenge. Hydrogen from renewables for fuel cell-driven vehicles might be a long term option, but its

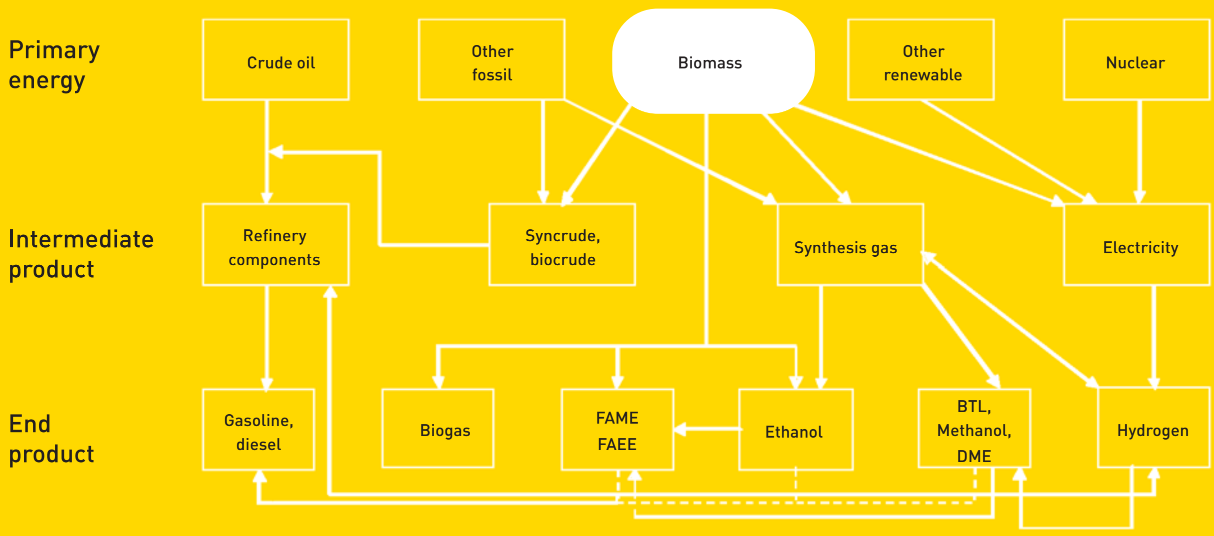

Figure 5.1: Process chains for fuel production (see Table 2.1 for explanation of abbreviations).


introduction will take a long time, needs breakthroughs in technology and cost and will require intermediate steps to enable a gradual growth of both fuel and vehicle availability.

Improving existing conversion technologies

Further progress is required to improve the energy and therefore carbon balance of existing technologies. This can be achieved by using innovative processes for biomass conversion and fractionation of products: thus new developments in the areas of catalytic and separation processes (such as membranes, new adsorbents, ionic liquids or supercritical extraction) can lead to improved energy efficiency and better thermal integration.

Ethanol production from starch can advance in economic and environmental performance by increasing the yield and improving the quality of co-products. New enzymes and processes can bring starch ethanol to competitiveness with fossil fuels in the short term.

In the case of FAME, FAEE and other derivatives, new catalytic processes such as those based on heterogeneous catalysis could be used to increase the yield and economics. The use of alternative sources of fatty acids (alternative oil-seed crops, GM) has to be considered. The quality of by-products is also an important factor. Improving the purity of glycerol can improve significantly the competitiveness of FAME production. The optimal use of by-products as intermediates for the production of fine chemicals or pharmaceuticals should also be considered. Biological processes (e.g. based on lipase enzymes) for biodiesel production from vegetable oil (typically rapeseed oil in Europe) could represent a significant advance over the present-day process of chemical modification.

Diesel fuel can also be produced by hydro-treatment of vegetable oil and animal greases. The technology has reached the demonstration stage and could be implemented soon. It is promising in being flexible in terms of feedstock, but requires integration with an oil refinery in order to avoid building a dedicated hydrogen production unit and to maintain a high level of fuel quality.

For biogas, key issues are maximising biogas production during the digestion process and gas purification (upgrading). It is also an option to process the biogas further or to produce synthetic natural gas (SNG).

The design and operation of existing biofuel plants is largely based on empirical experience. Therefore, the acquisition of thermodynamic, fluid dynamic and kinetic data is required for optimisation of existing, and the development of, new processes. Improving the analysis and characterisation of biochemical components, process fluids and mixtures are needed. More effective modelling methods for process and plant optimisation should be developed.

Production of ethanol and ethanol derivatives from cellulosic biomass

Advanced conversion technologies are needed to produce ethanol and ethanol derivatives from a wider range of resources, including lignocellulosic biomass (see Fig. 5.2). A wide range of lignocellulosic biomass wastes can be considered from agriculture (e.g. straw, corn stover, bagasse), forestry, wood industry, and pulp/paper processes.

New processes have also to be considered to produce derivatives, for direct incorporation into the fuel market, especially the fast growing diesel pool. Such processes include the transformation of ethanol into esters produced from vegetable oils (FAEE), which can be produced in the short to medium term. New derivatives such as higher alcohols (or ketone-alcohol mixtures) should have optimal properties with respect to both gasoline and biodiesel additions/substitutions. Modern methods of biotechnology would allow the construction of novel cellular production pathways for the best suited components, based on fermentation processes.

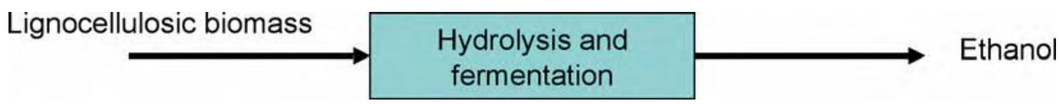

Figure 5.2: Production of 2nd generation biofuels by fermentation from lignocellulosic biomass.

Cellulose and hemicellulose can be converted into alcohol, by first converting them into sugar, but the process is not yet proven at an industrial scale. Lignin cannot be converted by such a biochemical process but can be via a thermochemical step, as discussed below.

Today, there is little commercial production of ethanol and ethanol derivatives from cellulosic biomass, but R&D is ongoing in Canada, USA and also in Europe.

Further progress is thus required to bring such conversion processes to the market. This includes more efficient biochemical systems (new enzymes, yeasts), innovative fractionation and purification processes and efficient uses of co-products. Additionally, the flexibility of conversion plants has to be improved in order to enable conversion of a broad range of lignocellulosic feedstock.

Production of synthetic fuels through gasification

A wide range of biomass feedstock can be used to produce synthetic fuels including DME, methanol, F-T diesel and F-T kerosene. In particular, the conversion of lignocellulosic biomass appears very attractive as a medium to long term prospect for producing a large quantity of biofuels. Although this option is not yet commercially proven, much R&D is ongoing, especially in Europe. Lignocellulosic biomass transformation processes under development are summarised in Figure 5.3.

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Technical innovation is needed to reduce the cost of the transformation and to improve the reliability of the technologies. Further progress has to be made to improve the pre-treatment and syngas purification steps, producing oxygen required by the gasification step in a more economic way, achieving better energy integration and improving the carbon balance. Another area to be explored is the possibility of increasing the overall yield by using external hydrogen. The optimal use of by-products and the treatment of waste streams (including waste water) are also important issues.

An alternative or parallel route to gasification is transforming the biomass into a liquid "biocrude", which can be further refined, used for energy production or sent to a gasifier. Such processes include fast pyrolysis and hydrothermal upgrading.

Combination of various technologies could also include gasification and further biotechnological conversion of CO_2 and H_2 into liquid fuels (such as ethanol or other compounds). This would be analogous to the chemical Fischer-Tropsch catalyst, but be based on a novel "cell factory". Advantages would include higher stability towards impurities, e.g. sulphur compounds), milder reaction conditions and better energy balance.

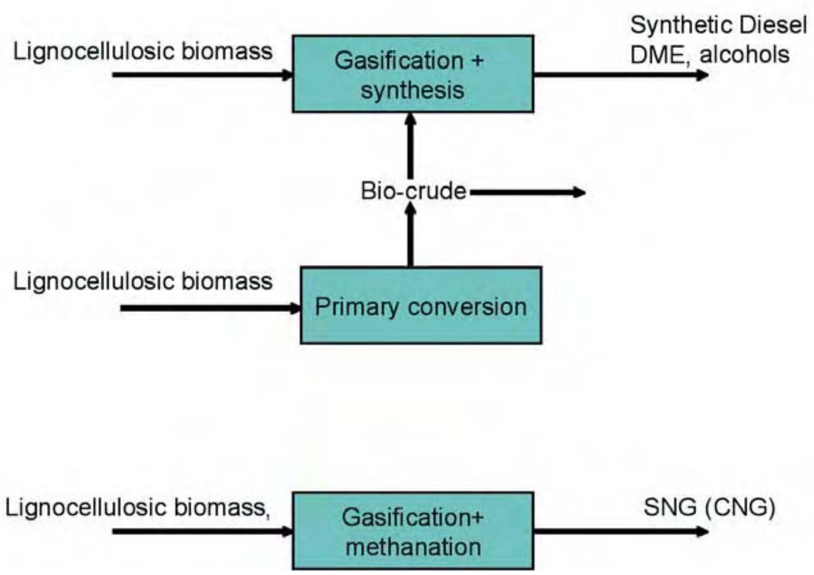

Figure 5.3: Production of second generation biofuels by gasification from cellulosic biomass.

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Development of integrated refining concepts

The expected growth of the biofuels market and the development of new transformation pathways make it timely to investigate new integrated production systems (biorefineries). Biomass-processing plants will need the same type of facilities as chemical plants. Integration of new biorefineries with existing industrial complexes appears to be a way to reduce total capital cost and lower the cost of the end products. This optimal integration has to take into account different possibilities (Figure 5.4):

- Production of a wide range of fuels and by-products from diverse lignocellulosic feedstock, whereas presently biomass conversion units are oriented mainly towards a single product (ethanol, FAME);
- Integration, in the same "biorefinery", of biochemical and thermochemical transformation stages;
- Optimal integration of oil and biomass refining sections to enable (i) the biochemical section to use hydrogen or low-grade heat from the oil refining section and (ii) the fractions produced in the biochemical section to be sent to the oil refining section;
- Optimal integration with traditional production facilities when appropriate, e.g. pulp and paper mills, sugar factories, oil mills;
- Co-processing in the same complex of oil, biomass, and possibly also coal, lignite, natural gas and biogas;
- Gasification of black liquor at pulp mills, with subsequent synthesis to fuels/chemicals.

An example of a biorefinery integrating biochemical and thermochemical transformation pathways is shown in Figure 5.5.

- Some relatively simple biorefineries already exist (e.g. sugar/ethanol plants, oil seeds crushing/trans-esterification plants, pulp and paper mills, biodiesel unit integrated into oil refinery). All alternative possibilities of integration will have to be explored. Conversion of intermediates and residues into valuable products is a central objective of the integrated biorefinery. The co-production of fuels and co-products, i.e. basic chemicals for synthesis purposes or high valuable minor components,

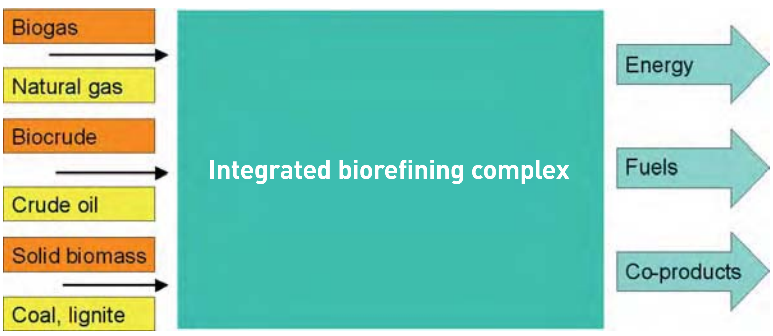

Figure 5.4: Example of an integrated biorefinery complex, co-processing different feedstock

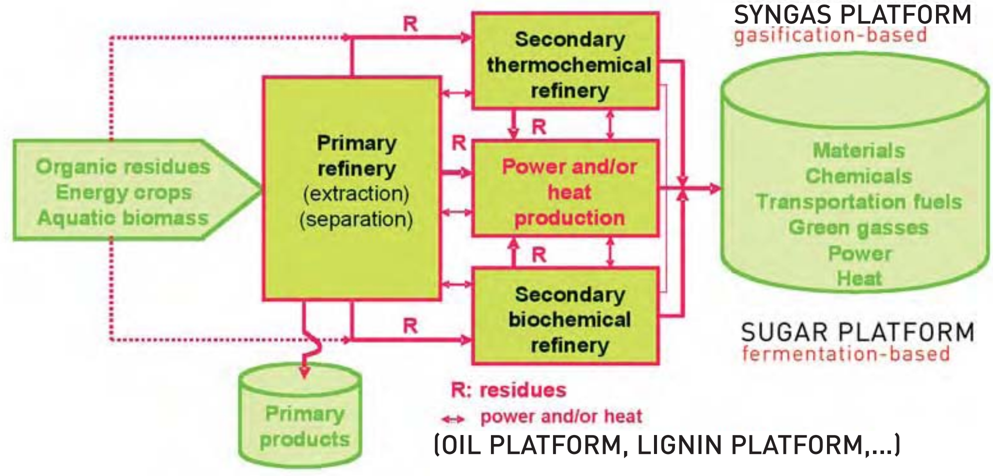

Figure 5.5: Biorefinery integrating biochemical and thermochemical transformation pathways, allowing energy-efficient use of a broad range of feedstock, and diversification of products.

can meet the challenges of economy and sustainability. Specific applications of biofuels for dedicated fleets or energy applications will also have to be taken into account. R&D is needed to investigate the optimal integrated schemes of production and identifying the best suited "building blocks". Adequate simulation tools will be necessary to support this process. Also, optimisation of the interfaces between biorefineries and existing logistic systems needs investigation.

In conclusion, there are many alternative types of biofuel and production processes. To ensure competition in the delivery of competitive, low carbon and secure biofuels it is important not to lock into one product or technology today, but to create an environment in which such products and technologies can evolve.

Vehicle engines

In 2030 it is foreseen that there will be only a few major powertrain/fuel combinations, one derived from the current spark ignition engine, one from today's compression ignition engine, and possibly another major engine based on a new combustion technology, i.e. homogeneous lean combustion. Thus, internal combustion engines will represent the majority of passenger car engines and close to 100% of the truck and bus engines in 2030.

The best option for biomass to be used for road transport is to convert it into liquid fuels, since these have the highest substitution potential (gaseous fuels will continue to grow but will remain in the lower 10% because of logistic restrictions).

The spark ignition (Otto-) and compression ignition (Diesel-) engine, and their after-treatment systems, will be further developed to achieve 'close to zero' emission requirements, emission durability and energy efficiency. There is intensive research ongoing that aims at combining these combustion processes to achieve improved fuel consumption and raw emissions performance (for example homogenous combustion compression ignition – HCCI, combined combustion system – CCS, combined auto ignition -CAI). Until 2030 these developments will have a considerable impact on engine technology. There might be minor markets for other vehicle technologies using similar or other dedicated fuels or niche markets for "innovative solutions", e.g. prototypes/concept cars based on fuel cells.

For the development and implementation of biofuels two major topics evolve from engine aspects: (1) joint development of new combustion processes and the most appropriate fuel type and specification, and (2) fuel optimisation for future exhaust emissions requirements for both conventional engines and the new engine developments.

Developments in sensors, monitoring and control may allow for some fuel flexibility in the marketplace. For spark ignition engines, systems that can identify fuel characteristics very precisely and adapt engine calibration to the specific fuel will be improved and extended to different fuel mixtures. The development of these "Flexi Fuel" vehicles could result in a much greater use of ethanol than possible today as a blending component. However, high fuel quality must be ensured to guarantee proper and durable after-treatment performance as well as stable and accurate sensor performance.

Biomass resources and logistics

Biomass resource systems should be optimised in order to match the quality characteristics of the existing and future feedstock to meet the requirements of the technologies and the end products. Furthermore, an integrated approach requires that, in some cases, the residues from forestry, industry, agriculture and other sectors, which are appropriate for energy applications, should be considered as fuels and not as wastes. Their final conversion to biofuels should be facilitated.

In the Nordic boreal forests there are large possibilities to increase the production of biomass with new management systems and further development of current systems. The possible production increase is estimated to be at least 30% until 2030.

Agriculture and forest-derived material must be processed on a decentralised basis to avoid uneconomic shipping costs. An option to be considered is pre-processing difficult to handle biomass and transporting the processed form. This is more efficient both in terms of energy value per transport unit and reduced costs. Due to the bulky nature of biomass, road transportation is expensive relative to the value of the product and affects carbon and energy balances. Ideally feedstock will be sourced close to end uses.

Logistic techniques should be improved along with adjusting the supply area and resource management according to the size of the plant, e.g. round bales, pellets, etc. Existing logistics for perennial energy crops are currently inadequate to meet the feedstock performance targets. Large-scale trials should be performed in order to design appropriate logistics systems from field to conversion facilities. Existing equipment should be improved and tailored to meet the needs of harvesting bulky quantities of residues as well as energy crops in a sustainable and cost effective manner.

Research efforts should also focus on the storage requirements and methods for multiple crops in order that they can flexibly cope with feedstock in wet or dry form depending on the material, time of harvest, form of harvested material (e.g. stems, bales, loose material), stage of maturity, environmental conditions, geography and processing use.

6 Deployment

Technology roadmap

Large-scale deployment of biofuels can be expected by 2020-2030. It is nevertheless necessary to identify the intermediate steps and likely timeline for development of the new options required for a strong biofuels industry and a significant biofuel use in Europe. As represented by the scheme in Figure 6.1, three main phases are to be considered:

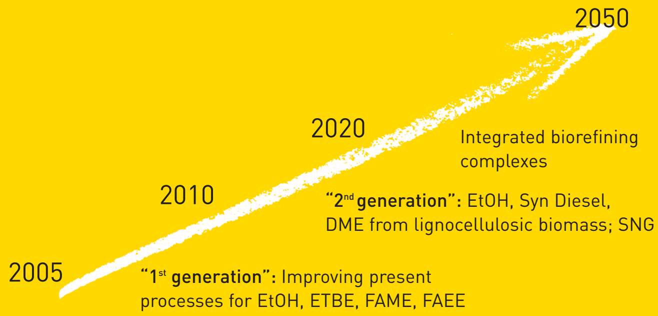

Figure 6.1 - Anticipated future roadmap

Phase I Short term (until 2010)

- Improving existing technologies;
- R&D into 2nd generation biofuels (from lignocellulosic biomass). First 2nd generation biofuels demonstration plants;
- R&D into the biorefinery concept.

Phase II Medium term (2010 - 2020)

- Deployment of 2nd generation biofuel production
- Demonstration of biorefinery concept; continued R&D to improve lignocellulosic biofuel; and integrated biorefinery processes;
- Development of options for energy crops and sustainable agriculture.

Phase III Long term (beyond 2020)

- Large-scale production of 2nd generation biofuels; deployment of integrated biorefining complexes

Liquid biofuels, which are compatible with current technology, offer the highest potential for fast introduction of biofuel on a large scale. The preference for liquid fuels from biomass does, however, not mean that there is no place for gaseous fuels in this strategy. Biogas (methane) is likely to replace an increasing share of the CNG in automotive fuel market.

The external supply of hydrogen considerably increases the fuel yield from a given volume of biomass. The use of renewable hydrogen as a component in fuel production processes from biomass (or other carbon-containing primary energy source) is an option for today's fuel routes via synthesis gas, but will also be a serious option for future "biorefineries" that will produce a range of products from biocrude. Although the combination of biomass conversion and external hydrogen supply adds to a system's complexity and cost, this option has to be considered in future fuel routes from biomass.

Cost competitiveness

A key factor in the deployment of biofuels is cost competitiveness or cost effectiveness. This does not only refer to the production of biofuel itself, but also to other associated costs, such as investments in new vehicles or alternative logistic systems. Cost reductions will be achieved by using advanced technology, through an economy-of-scale effect and a better integration into the fuel supply chain.

Sustainability

Mechanisms need to be put in place in order to ensure that the whole chain of biomass and biofuels production is sustainable. This requires options for efficient and sustainable crops and involves the promotion of both the primary and residual forms of agricultural and forestry operations. Whilst biomass production and energy exploitation is favourable in terms of global GHG emissions, care should be taken when planning at local level. The production of energy crops should comply with the existing regulations, e.g. "cross-compliance" with agriculture. Land strategies have to introduce a number of crops and forestry management schemes selected according to regional characteristics and needs.

Thus, the entire value chain needs to be evaluated for biofuels using a "well-to-wheels" analysis. This requires optimisation of the geographical location of production facilities and the origin of feedstock. Production and feedstock supplies need to be assessed globally, taking account of different growing conditions (climate) and labour costs.

Non-technological aspects

Legislation, regulations and standards

Legislation is a key element in promoting biofuels. One big challenge is the lack of harmonisation amongst member states with national agendas often taking precedence. Clear long-term, EU legislation is vital to help secure supply and competition in the market and to make the investment climate for biofuels favourable.

Legislation promoting biofuels could be based on tax incentives, mandates to use biofuels or via emission standards. Creating a market advantage for biofuels will also speed up RTD and make it more target-oriented. Incentives should be structured in such a way that all kinds of biofuel use – as a neat fuel, as a fuel admixture or as a refinery component (e.g. biocrude) – are treated equally.

To ensure the reduction of CO_2 emissions, a market mechanism will be required to ensure that CO_2-efficiency of bio-fuels is acknowledged and rewarded. Currently biofuel tax incentives or quotas do not differentiate biofuels based on their CO_2 balance. Mechanisms (e.g. a certification scheme) could be used to promote the use and production of "more CO_2 effective" biofuels and bioproducts.

Agreed quality standards for biofuels and biofuel blends are mandatory. These standards should be developed in consultation with all relevant stakeholders. The quality aspect of fuels from biomass is even more important for developing and emerging countries, which may not yet have fuel standards equivalent to those in Europe, US or Japan. The admixture of ethanol (or ETBE) for instance may help to facilitate the introduction of lead free gasoline. The development of fuels from biomass in Europe has to take into account also the situation in countries outside Europe, especially those with fast growing economies.

Furthermore, it is important that bio-residues from forestry, agriculture and other sectors are not classified as waste but are considered as a potential feedstock for fuel.

Domestic biomass production and international trade

EU agriculture is mainly based on food production. The sector has not fully prepared for non-food production. To compete globally in the biofuel feedstock markets, the sector needs to rationalise and optimise its operations. Moreover, land strategies must be carefully planned so that the labour costs are not extremely high and the EU can withstand global competition. These land strategies must be sustainable and compatible with the climatic, environmental and socio-economic conditions prevailing in the region.

The IEA Bioenergy Task 40 (www.fairbiotrade.org) reports that Latin America and Sub-Saharan Africa present significantly higher potentials than Europe and even North America. In developing countries production and use of biomass is expected to improve and enhance their unstable agricultural systems. Biomass should be produced and used where it is economically most viable. This approach would give opportunities to developing countries, which have their economies based on agriculture, but which suffer from low agricultural product prices.

There is an increasing international trade of raw materials for energy and biofuel purposes and this must be taken into account when considering future resource availability. Biofuels and their raw materials are traded on world markets, despite the bulky nature and low calorific value of the raw materials. It is important that biomass trade is regulated not only with quality and safety protocols but also with sustainability standards.

The Biomass Action Plan [6] assesses three routes to a 5.75% market share for biofuels: (1) minimum share for imports, (2) maximum share for imports, and (3) a balanced approach. The Commission has indicated that it prefers the balanced approach and will take appropriate objectives forward to bilateral negotiations (e.g. with Mercosur) and multilateral negotiations (e.g. the Doha World Trade Organisation round and discussion on trade in environmental goods).

Communication and co-ordination of RD&D

The communication channels to key actors need to be strengthened. In particular, the awareness should be enhanced of Municipal Solid Waste companies (for the energy potential of their wastes, along with policy measures to promote waste to energy) and farmers (for energy crops and for the energy value of current food crops and respective residues/by- products).

A good coordination between major European industrial actors is paramount. Such coordination could be facilitated by joint innovation programmes and joint operation of experimental facilities. A European Technology Platform for Biofuels can play a crucial role in the implementation of such innovation programmes, and can provide the scenarios and strategic guidance for decision makers to set up the proper policy framework. The Biofuel Technology Platform should make recommendations for research in this sector by elaborating a Strategic Research Agenda, and actively support its implementation.

7 Recommendations

By 2030, up to one quarter of the EU's transport fuel needs could be met by clean and CO_2-efficient biofuels. In order that this can be realised, the following is recommended:

1. There are many alternative types of biofuel and production processes. To ensure competition in the delivery of competitive, renewable and secure biofuels it is important not to lock into one product or technology today, but to create an environment in which such products and technologies can evolve.

2. For conventional biofuels, further progress is required to improve the energy and carbon balance of existing technologies. This can be achieved by using innovative feedstock and processes for biomass conversion and products fractionation, supported by advanced modelling methods and acquisition of chemical engineering data for process and plant optimisation.

3. Advanced conversion technologies are needed for second generation biofuels. New methods are needed for ethanol production from a wider range of resources, including lignocellulosic biomass. Gasification of lignocellulosic biomass is a promising technology for the large-scale production of biofuels for road, marine and air transport (gasoline- and diesel-type fuels, kerosene, DME and others).

4. The expected growth of the biofuels market and the development of new transformation pathways make it timely to investigate new integrated refining schemes. The biorefineries will be characterised by an efficient integration of various steps, from handling and processing of biomass, fermentation/gasification in bioreactors, chemical processing, and final recovery and purification of the product.

5. For supply of the biomass feedstock, sustainable land strategies must be created that are compatible with the climatic, environmental and socio-economic conditions prevailing in each region. The use of both primary and residual products from agriculture and forestry should be promoted. The issue of competition for biomass resources should be properly addressed.

6. Dedicated energy crops and the use of biotechnology will allow more efficient use of the whole crop, resulting in an increased and continuous supply of feedstock with uniform characteristics.

7. The development of advanced and efficient powertrains, including flexible fuel engines, both for light and heavy duty vehicles, is paramount. These technologies should aim at optimising the utilisation of energy on a well-to-wheel basis. The introduction of new, advanced engines would require a clear framework and planning.

8. Agreed quality and environmental standards for biofuels and biofuel blends are mandatory. These standards should be developed in consultation with all relevant stakeholders.

9. Biofuels and their raw materials are traded on world markets. A fully self-sufficient approach to meet the EU's needs is neither possible nor

desirable. The Commission should pursue a balanced approach in encouraging both domestic production and imports. Export of European biofuel technology to countries that export biofuels to the EU will help the EU biofuel technology industry to achieve and maintain a competitive position globally.

10. A full deployment of biofuels can be expected by 2030. To achieve this, optimal co-operation between stakeholders from research, agriculture, forestry and industry is vital. A good co-ordination between major European actors will be essential and would be facilitated by joint innovation programmes and joint operation of large demonstration facilities.

11. A European Technology Platform [11] for Biofuels should be established. Its scope should include biomass-based fuels for road, water and air transport.

12. The Technology Platform should support further development and deployment of currently available fuels, and it needs to strongly promote the transition towards second generation biofuels, which will be produced from a wider range of feedstock and which will help to reduce costs of "saved" CO_2. Attention should be paid to the issue of cost-effectiveness and to assessing and monitoring the full environmental impact of biofuels.

13. The Biofuels Technology Platform should establish and maintain close links to other relevant Technology Platforms such as ERTRAC (road transport), Forest-based Sector, Plants for the Future ("green" biotechnology), Sustainable Chemistry (including "white" or industrial biotechnology) and Hydrogen & Fuel Cells, as well as to national platforms and other RTD&D initiatives in EU Member States.

14. The EU is supporting biofuels with different policy measures. Harmonisation of policy measures is a complex, cross cutting and dynamic task, and requires a thorough impact assessment to examine what the economic and environmental effects of an increased use of biofuels would be. The Biofuels Technology Platform can provide an agreed analytical base to assist all Commission services concerned (e.g. Directorates-General Research, Energy and Transport, Trade, External Relations, Agriculture and Rural Development, Environment, and Economic and Financial Affairs).

Successful implementation of the above will help ensure that a substantial part of the biofuels market is provided by a competitive European industry based on sustainable and innovative technologies, creating opportunities for biomass providers, biofuel producers and the automotive industry. The established and operational Biofuels Technology Platform will provide the scenarios and strategic guidance for decision makers to make it happen.

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The report of the Biofuels Research Advisory Council (BIOFRAC) presents a vision for biofuels in the European Union. By 2030, up to one quarter of the EU's transport fuel needs could be met by sustainable and CO_2-efficient biofuels, of which about half is to be provided by a competitive European industry.

The report outlines the current situation and presents a long-term view on how to overcome the technical and non-technical barriers for biofuel deployment in the European Union and worldwide.

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