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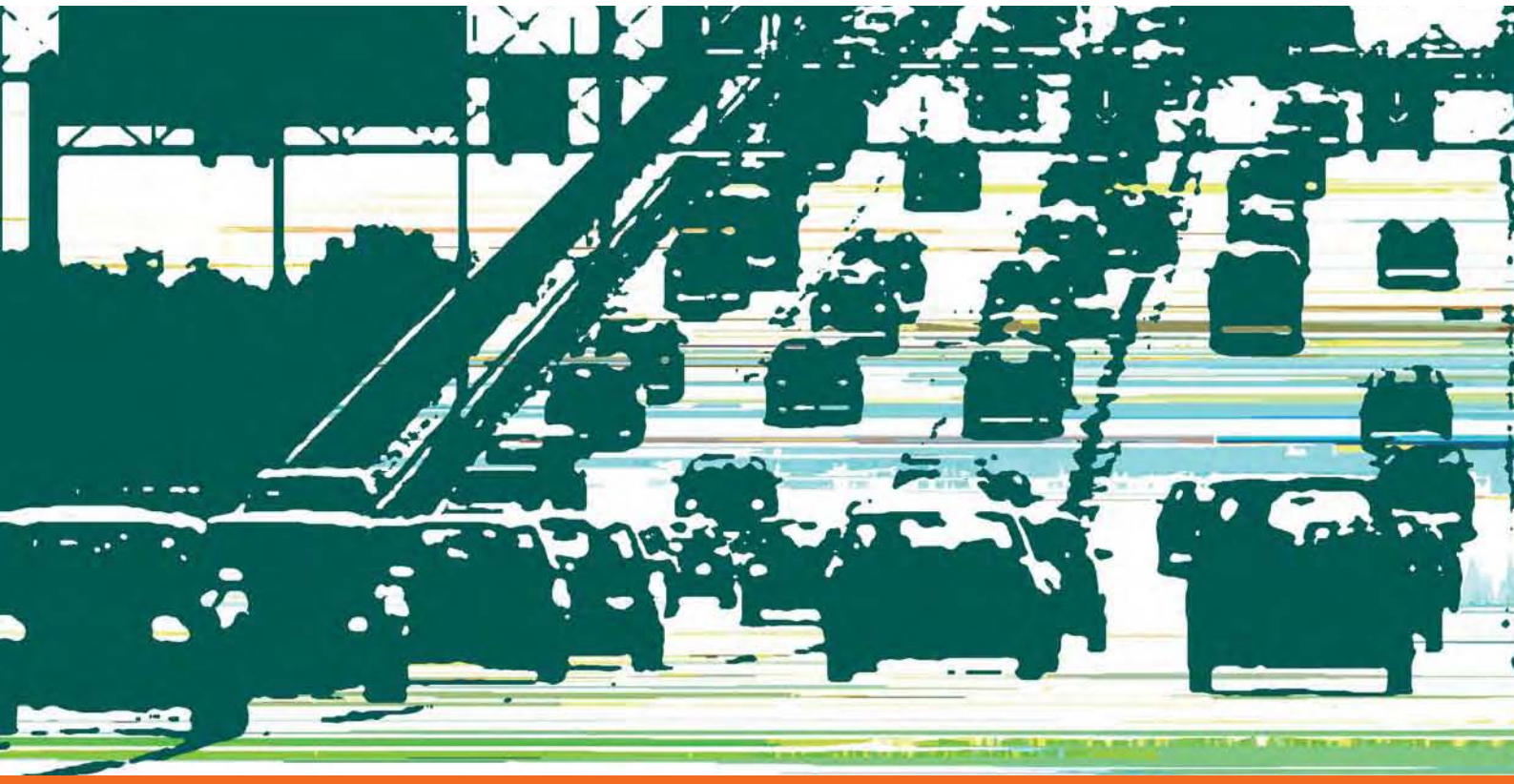

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Biofuels
in the European Union

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.

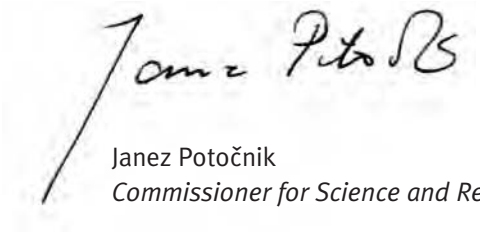
In an effort to better prioritise, co-ordinate and implement future research and development of biofuels, the Commission invited a group of high level experts representing widely different sectors of the biofuel chain. The mission of this group was to develop a foresight report – a vision for biofuels 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

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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.

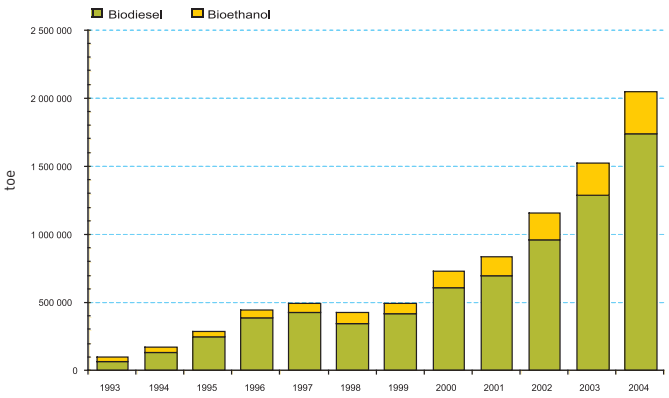

Figure 2.1: Biofuel production in the EU since 1993. (2004: EU25). Source: Eurobserv'er 2005.

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).

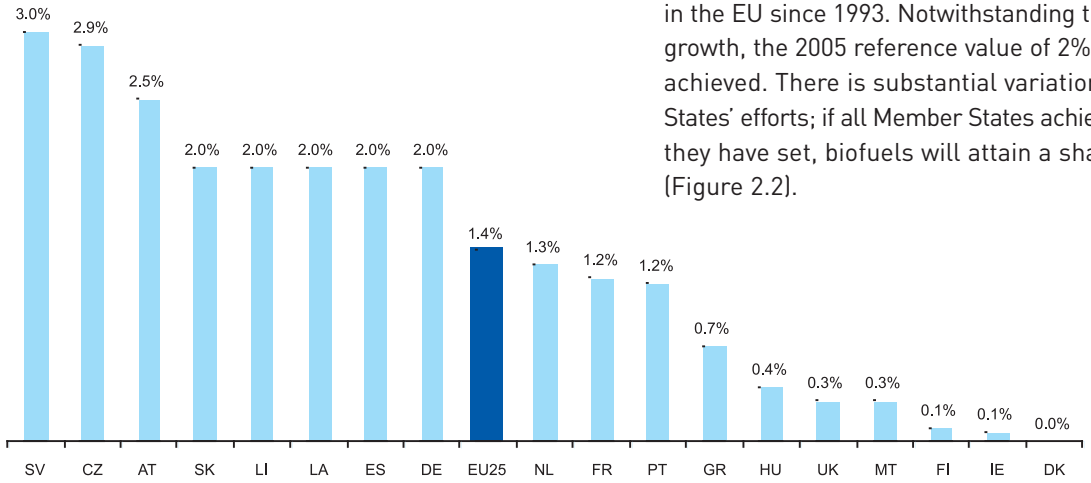

Figure 2.2: Biofuel targets for 2005 (EU25). Source: European Commission.

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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.

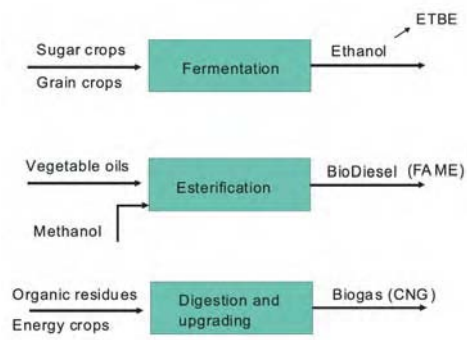

Figure 2.4: Present biomass transformation processes.

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

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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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