Biofuels
TECHNOLOGY PLATFORM

European Biofuels Technology Platform

Strategic Research Agenda & Strategy Deployment Document

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Preface

Members of the European Biofuels Technology Platform (BiofuelsTP) have been working for more than a year to produce a collective view of the main Research, Development and Demonstration (R&D&D) priorities, as well as accompanying deployment measures, which are required for a successful implementation of a competitive and healthy European biofuels industry. The initial findings, published as a draft document have been open to public consultation. We have received more than 500 contributions that, where appropriate, have been taken into account enhancing the final outcome.

We are now happy to present our final Strategic Research Agenda (SRA) and Strategy Deployment Document (SDD) as our contribution to the biofuels community and in particular to all those stakeholders that share the vision that biofuels will in future cover a significant part of road transport fuels needs. Very ambitious biofuels targets have been set for the European Union. Hence, we already know what are the challenges and what is the range of technologies that can contribute to overcoming them. Now, it is time for action. R&D&D need to be accelerated and production facilities installed to produce high quality biofuels that are sustainable, competitive and socially accepted.

This is our vision.

Luis Cabra, Chairman, Steering Committee, European Biofuels Technology Platform

Highlights

- The SRA identifies key R&D&D priorities required in order to reach the vision of up to 25% substitution of road transport fossil fuels by biofuels in 2030.
- The SRA represents the collective views of over 150 individuals representing stakeholders (industry, academia, research, associations) with an interest on biofuels R&D&D.
- Three main areas of technology development have been covered: biomass production and supply, conversion processes and end use.
- Winning technologies will be those that best address strategic targets (GHG reduction , security of energy supply and economic competitiveness) in a sustainable way.
- An integrated development of biofuels, conventional fuels and engines will help establish a cleaner and more energy efficient road transport system.
- A coherent, long-term, harmonised policy framework is required, leading to more flexible and open markets in order to secure the confidence of investors.
- Joint public/private financing of R&D&D is required, with additional public funding required for higher risk large-scale demonstration facilities.
- Social awareness needs to be increased and social acceptance gained by open communication of the benefits as well as potential drawbacks of biofuels.

Executive Summary

This document presents the Strategic Research Agenda (SRA) of the European Biofuels Technology Platform (BiofuelsTP). The SRA aims to provide solutions and highlight the Research, Technology Development and Demonstration (R&D&D) efforts required to achieve the Vision for Biofuels in Europe as set out in the Report of the Biofuels Research Advisory Council (BIOFRAC) '*Biofuels in the European Union - A vision for 2030 and beyond*'. An accompanying Strategy Deployment Document (SDD) discusses the non-technical issues that have also to be considered in developing the European biofuels market for road transport to its full potential.

European energy consumption is strongly dependent on fossil fuels, including a significant amount of imported oil and gas. Imports account for around 80% of the EU gross inland consumption. The dependence on imported fossil fuels is greatest in the case of oil. 98% of road transport depends on petroleum oil, a finite resource that raises concerns in terms of security of supply. Transport is the only sector that shows a significant increase in CO_2 emissions over the past 15 years. This trend is expected to continue, making it difficult to achieve the Kyoto targets and compromising the EU leading efforts against climate change.

Increasing the use of biofuels for transport is one of the mechanisms by which the Community can reduce its dependence on imported oil and oil products thus improving the security of energy supply in the medium and long term. Greater use of biofuels for transport forms also an important part of the package of measures required if the EU is to comply with CO_2 reduction commitments and policy targets.

Today, biofuel production in Europe is significantly limited in volume and is not fully sustainable due to limited availability of raw materials that compete with food and other uses and have high costs. In the future, biofuels must perform better, in terms of overall environmental sustainability, than the fossil fuels they replace and new biomass-conversion pathways have to be developed in order to reach the large volumes required to meet ambitious EC targets. This has to be proven by robust analysis and also shown to be socially acceptable on a local as well as a global level.

The BiofuelsTP Working Groups have identified critical areas in which technology development will play a key role towards the successful implementation of sustainable and competitive biofuels in the EU:

Feedstock:

- Managing competition for limited land resources (food & fodder vs bioenergy) and for different biomass applications (transportation fuels, heat, power, industrial raw materials).
- Increasing yield per hectare and developing efficient supply logistics both for dedicated crops and residues.

Conversion technologies:

- Developing energy efficient and reliable biomass-to-fuel conversion processes with feedstock flexibility and high quality products.

End-use technologies:

- Optimisation of fuel-engine environmental and energetic performance, ensuring compatibility with existing and future infrastructure and vehicles.

The winning options (combination of land, feedstock, conversion and end product) will be those best addressing strategic and sustainability targets:

- High level of GHG reduction with sound management of other key environmental issues (biodiversity, water use, local emissions, etc).
- Security and diversification of energy supply for road transport.
- Economic competitiveness and social acceptance.

Both strategic fit and sustainability potentials have guided the work of identifying and prioritising key R&D&D efforts needed. Newer technologies will require more integrated R&D&D efforts while more mature technologies work should focus on further development and demonstration of improvements from the very short term. Thus, for the above mentioned critical areas of technology development, the following R&D&D priorities have been identified:

Feedstocks:

- Develop availability-cost curves for different sources of biomass (energy crops, forestry and agriculture residues, wastes) and geographical locations.
- Develop new high-yield and low-input agricultural and forest systems with breeding of crops and trees optimised for biofuel production.
- Develop efficient biomass logistic systems (harvesting/collection/storage) for different conversion concepts at different scales.

Conversion processes:

- Improve current conversion processes to their full potential (biodiesel, bioethanol from starch-sugar) for higher GHG reduction, increased flexibility for different raw materials and lower cost.
- Develop thermochemical and biochemical conversion processes with feedstock flexibility for different lignocellulosic biomass (BtL, L-C bioethanol).
- Develop integrated biorefinery concepts making full use of a variety of biomass feedstocks to obtain diverse high-value bioproducts.
- Demonstrate both at pilot and industrial scale reliability and performance of new technologies.

Fuel/engine optimisation:

- Establish conditions for compatibility of biofuels and biofuel blends with existing logistics, as well as existing and new powertrains; develop vehicle modifications for neat biofuels and high blends for specific market needs.
- Generate engine-fleet test data and set sound quality standards for biofuels.
- Develop in-depth understanding of relationship between biofuel quality and engine performance for future fuel/powertrain systems in order to deliver superior combined performance.

Overall system sustainability:

- Further develop indicators and coherent methodology to assess and monitor the three dimensions of sustainability: economic, environmental, social.
- Generate and collect data required and carry out sustainability assessment of existing and potential promising production chains (land, feedstock, process, fuel use).

In order to develop the European biofuels to its full potential, a number of non-technological deployment measures have to be addressed also under coordinated and target-oriented efforts:

- A coherent, long term and harmonised political and open market framework to secure confidence of investors in capital-intensive innovative technologies.
- Joint public/private financing for R&D and Demonstration of new biofuel production routes and end-use applications. Additional public funding for higher risk large-scale demonstration facilities.
- Biofuel quality standards which are based on sound science while not creating unnecessary barriers for biofuel deployment.
- A simple, coherent and global certification system to assure environmental sustainability of biofuel production chains.
- Social awareness needs to be increased and social acceptance gained by open communication of benefits as well as potential drawbacks of biofuels.

STRATEGIC RESEARCH AGENDA

1. INTRODUCTION

This document presents the Strategic Research Agenda (SRA) of the European Biofuels Technology Platform (BiofuelsTP). The SRA aims to provide the answers and highlight the Research, Technology Development and Demonstration (R&D&D) efforts required to achieve the **Vision for Biofuels in Europe** as set out in the Report of the Biofuels Research Advisory Council (BIOFRAC)[1] '*Biofuels in the European Union - A vision for 2030 and beyond*'. An accompanying document on Strategy Deployment, discusses the nontechnical issues that also have to be considered in developing the European biofuel market for road transport to its full potential.

The SRA covers the technology developments in areas of biomass production, biofuels conversion processes and biofuels end use for road transport, which are required to meet the Vision, offering insight and guidance with emphasis on the sustainability of biofuels. As indicated in section 1.5, the SRA has focused on liquid biofuels, although it is realised that biogas and biohydrogen can also be used as road transport fuels. However, liquid fuels are the preferred choice for road transport due to their relatively higher energy density and the fact that their use, particularly as blends, is more compatible with existing fuel distribution systems and requires little or no modification to power trains.

[1] *Published 2006, Directorate-General for Research, Sustainable Energy Systems, Ref: EUR 22066. (Biofrac. 2006. Biofuels in the European Union. A vision for 2030 and beyond.)*

1.1 The Objective

The primary objective of the SRA is to identify the key Research, Development and Demonstration (R&D&D) activities that are required in order to reach a successful EU biofuels industry that contributes to the BIOFRAC vision goal with biofuels providing up to 25% of road transport energy needs in the year 2030 covered in a cost-competitive, economically viable and sustainable way. The SRA is a tool that will facilitate all EU stakeholders to co-ordinate and plan coherent R&D&D activities. The SRA is a statement of R&D&D priorities. It includes time lines for the development of both improved and new feedstock and conversion technologies and identification of the necessary steps, with recommendations for implementation in both public and private programmes.

The SRA does not formulate a detailed research work program. Such formulation has to be the responsibility of competent organisations in the public or private sectors. By highlighting the perceived needs, the SRA offers guidance to such bodies and is thus expected to impact on EU, national and private R&D&D programmes. However, different stakeholders will have different roles in the implementation of the SRA, and therefore this requires synergistic and complementary interactions as the need for co-operation is recognised.

The Strategy Deployment Document also proposes mechanisms for collaboration and partnership in order to help define strategies for biofuels deployment and identify resources and requirements for regulatory measures as well as the implications of adopting such measures.

1.2 Background to the BIOFRAC and the BiofuelsTP

The Biofuels Research Advisory Council (BIOFRAC) was created by the European Commission (EC) who invited high-level experts of stakeholders from various sectors with interests in biofuels development, mainly from industry but also from academia and research organisations, to develop a long-term vision for biofuels and determine the need for a European Biofuels Technology Platform (BiofuelsTP).

The BIOFRAC group was united in its support of the idea and outlined the structure for such a platform, which was launched in June 2006. The EC endorsed this venture providing financial support for the Secretariat and formally recognised the TP in April 2007. The BIOFRAC Vision Report was adopted as an introduction and decision making instrument for the BiofuelsTP that was formed along the lines envisaged in the vision, which was adopted in terms of the proposed goals for 2030.

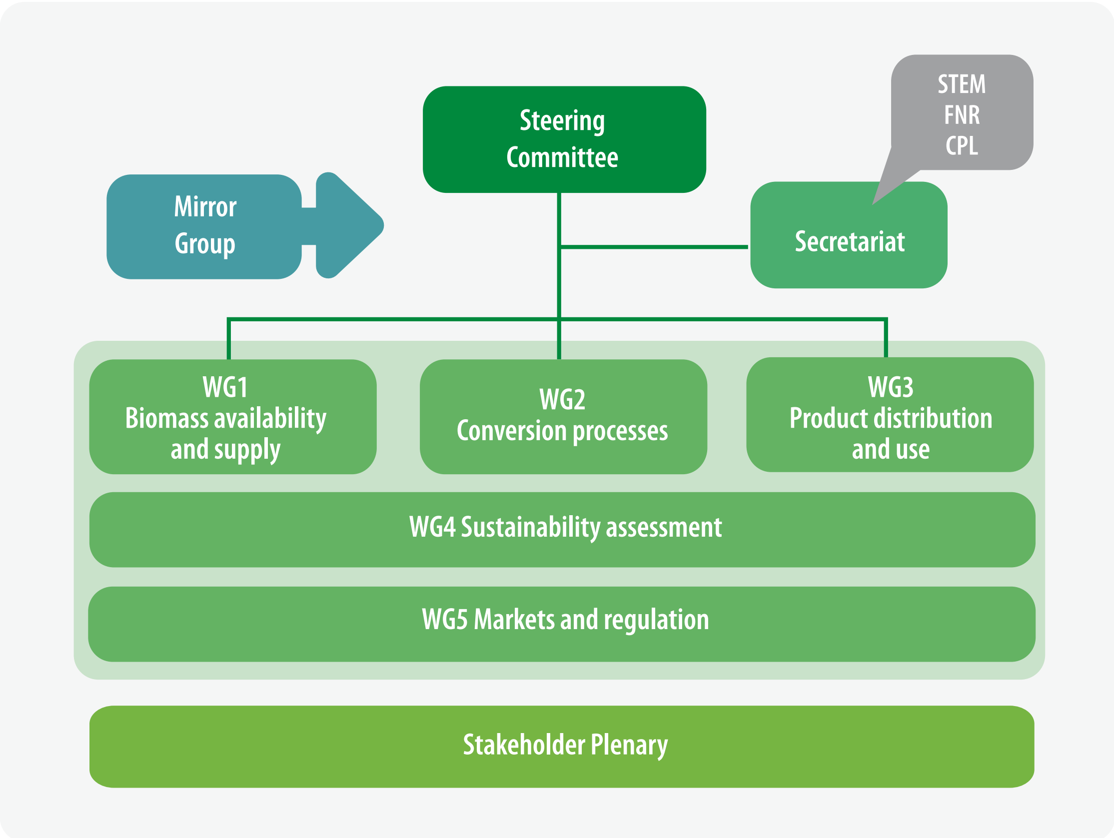


***Figure 1.1.** Structure of the European Biofuels Technology Platform*

The structure of the BiofuelsTP is shown in figure 1.1 below. Details of over 150 individuals who as members of the various bodies (Steering Committee, Workgroups and Secretariat) of the TP contributed to the report are given in Annex 1. Contributors to the BiofuelsTP report. The number of individuals, the organisations represented and the efforts made through a series of meetings held during the first half of 2007 clearly indicates the extent to which this report represents the combined views of all sectors of the biofuels community.

Much of the work was carried out by the five topic based workgroups, supported by the Secretariat. Members of the workgroups (WGs) represented all stakeholders with an interest on R&D&D: industry, academia, research organisations, common interest groups or associations with an interest in biofuels production and use. In general the members of the WGs were selected from individuals representing companies or organisations who responded to a call for expressions of interest issued by the EC following acceptance of the BIOFRAC report. For practical reasons, the number of individuals in each workgroup had to be limited to around 25.

Hence, additional selection criteria were adopted that included the technical experience of the individual and the extent of support offered by the organisation for which they worked. The initial activities were carried out by a series of workgroup meetings. These covered biomass production, conversion technologies, product distribution and use and sustainability as well as market aspects which includes the legal framework required for optimal development of this sector. Reports drafted by the WGs formed the basis for a preliminary document that was reviewed by a select taskforce and ratified by the BiofuelsTP Steering Committee.

The resulting draft document was presented as a consultation document to the biofuels community (Stakeholders) and to the public at large. Inputs from the consultation process have been made generally available through the BiofuelsTP website. The views expressed were taken into account in preparing the final SRA.

1.3 The importance of the Road Transport Sector in the Energy Equation

European energy production and consumption is strongly dependent on fossil fuels, including a significant amount of imported oil and gas. Imports account for around 80% of the EU gross inland consumption. The dependence on imported fossil fuels is greatest in the case of oil; domestic sources accounted for less than 20% of oil consumption. By 2030, import dependency on oil is expected to reach 94%. The Member States of the EU consumed 603 million tons of mineral oil in 2006 (MWV 2007)[2] of which 47% ended up as road transport fuel and 8% as aviation fuel (see Figure 1.2).

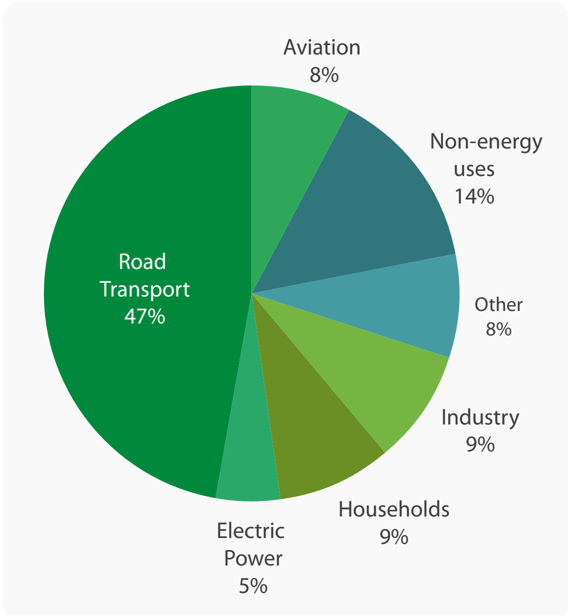


***Figure 1.2.** Petroleum products use by sector, Source: Eurostat 2007.*

[2] *Mineralölwirtschaftsverband (MWV; German Mineral Oil Industry Association). 2007. Jahresbericht Mineralölzahlen 2006: p.72*

98% of road transport depends on petroleum oil. This is a finite resource that also raises questions in terms of security of supply. An analysis of the growth of all types of transport shows that it has also been the main source of growth with respect to oil consumption, as oil use in the other sectors has generally been declining. An increasing consumption is associated with an increasing emission of Greenhouse Gases (GHG) (Figure 1.3). Carbon dioxide is by far the most significant energy related GHG, accounting for about 95% of man-made emissions.

Transport is the only sector that shows a significant increase in CO_2 emissions over the past 15 years. This trend is expected to continue, making it difficult for the EU to achieve the Kyoto targets that have been set. The perspectives of a foreseeable increasing use of transport fuels which also means an increasing oil and import dependency and increase in CO_2-emissions advice the EU to reduce fossil oil consumption especially in case of transport fuels.

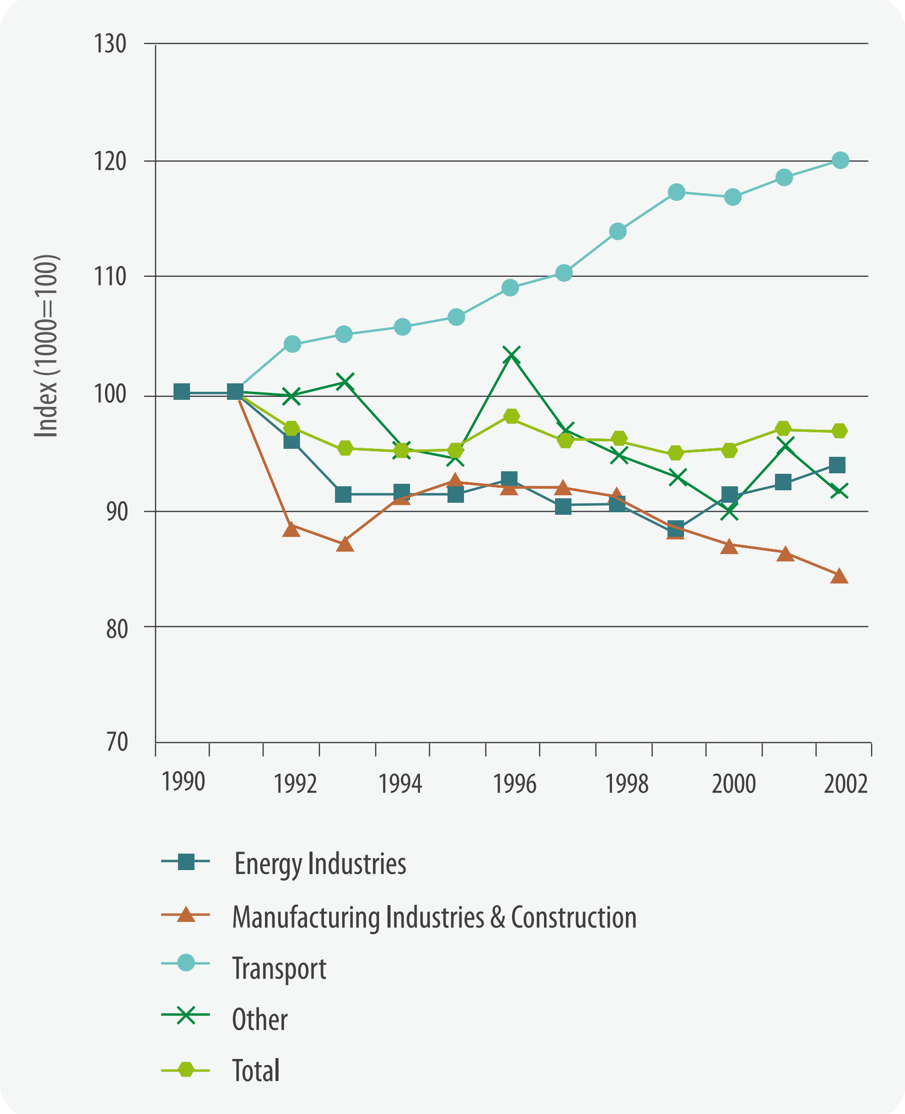


***Figure 1.3.** EU25 Total Emissions of Green House Gases from Fuel Combustion by Sector. Source: Eurostat (SEC (2007) 12)*

SWOT analysis for transport biofuels in the EU

Strengths

- Highly competent R&D capacity in EU27 in terms of human resources and research infrastructures, methodologies and tools.
- Good partnerships within and beyond EU borders, providing the basis for future research work and transfer of knowledge and technology.
- Funding within the current EU R&D Framework Programme (FP7) provides opportunities for development of biofuels both within and outside the EU.
- Critical mass for effective R&D including collaboration between the research and industrial communities.
- Political will and market demand is getting stronger for secure and sustainable biomass supply.
- Biofuels represent today one of the most significant options for the reduction of fossil CO_2 emissions from transport.
- Biofuels represent an alternative to set aside lands to satisfy the energy demand partially.
- Biofuels can contribute to the creation of new jobs.

Weaknesses

- Biofuels production is a cross-sectorial issue (energy, transport, agriculture, environment) requiring difficult to achieve consistency of policy.
- Biofuel production dependent on a complex matrix of feedstocks and processes with different characteristics and logistic/ handling requirements.
- Appropriate strategies have yet to be created to avoid disruption in feedstock supply.
- Large volume handling/ logistics are required for industrial scale production of biofuels, especially for lignocellulosic feedstocks, as current systems are designed to meet small- medium scale requirements.
- International competitiveness of current EU biofuels is poor due to high feedstock costs.
- Demonstration projects to prove technology development for next generation biofuels are lacking.
- Nowadays the raw materials used compete with the food sector.
- Low yields of energy crops in some European regions.

Opportunities

- Favourable political environment reflected in directives and policy documents, including the recent "Energy Package" confirmed by the European Council in March 2007.
- Priority given to biofuels research in the Seventh RTD Framework Programme (FP7) and bioproducts identified as a lead market.
- High oil prices tend to enhance the competitive position of biomass and biofuels in the market place.
- Increasing industrial interest in biofuels with substantial current investment, especially in current generation biofuels.
- Strong industrial chain from suppliers of biomass to end use of biofuels throughout EU 27.
- Biofuels can contribute to improved development of the agro-industry.

Threats

- Too long time lag between science and technology development and market implementation.
- Social perception on certain fields of plant biotechnology may hinder enhanced biomass production.
- Competition for land and biomass to meet the multi-functional markets of food, fibre, fuel, feed.
- High investment required to realize the 25 % vision target by 2030.
- A coherent and long term political framework has yet to be established in order to ensure efforts in R&D&D and create a stable scenario for investment in capital intensive new production units.
- Fossil oil prices unpredictable and possibly correlated with agro-feedstock prices.
- High cost of CO_2 avoided with biofuels compared to other options, including other bioenergy.
- Volume of today's available biofuels less than targeted, as feedstock is limited by competition with land used for food production.

1.4 Biofuels: The Key Issues

Why Biofuels?

Increasing the use of biofuels for transport is one of the key tools by which the Community can reduce its dependence on imported oil and oil products thus improving the security of energy supply in the medium and long term. However, this consideration should not detract from the importance of compliance with Community legislation on fuel quality, vehicle emissions and air quality.

Greater use of biofuels for transport forms an important part of the package of measures required if the EU is to comply with CO_2 reduction commitments from the Kyoto Protocol as well as of any policy packages set up to meet further commitments in this respect. Figure 1.4 shows potential GHG reduction that can be achieved with biofuels at penetration levels for 2020 and 2030 that will be presented below.

Well-to-wheel analysis is a key tool for assessment and comparison of the GHG potential and overall energy efficiency of fuel production pathways. The aim is to have the **lowest GHG emissions at the lowest possible energy use** for a specific amount of transportation. Figure 1.5 is indicative of the benefits that could be derived through greater use of biomass-based alternative transport fuels and shows their related overall energy usage. Although more energy intensive than crude oil based fuels, it is clear that different biofuel production pathways can lower GHG emissions as compared with conventional gasoline and diesel fuels. This is particularly the case for the so-called **second generation biofuels** (circled in figure 1.5).

Note: Well-to-wheel analysis is susceptible to choices of system boundaries and assumptions on specific emission coefficients (for example, the EUCAR/CONCAWE/JRC study in Figure 1.5 is regularly updated to reflect recent insights on these elements).

Biofuels Challenges

Today, biofuels production in the large volumes required to meet ambitious EC targets is not fully sustainable because of **limited availability of raw materials and high costs of production**. In the short to mid term biofuels will still need public support and a favourable regime. New technologies should focus on fully exploiting biofuels benefits (GHG reduction, reducing dependency on oil products) while facing challenges as widening the raw materials base and reducing manufacturing costs thus making biofuels socially and economically sustainable in the long term.

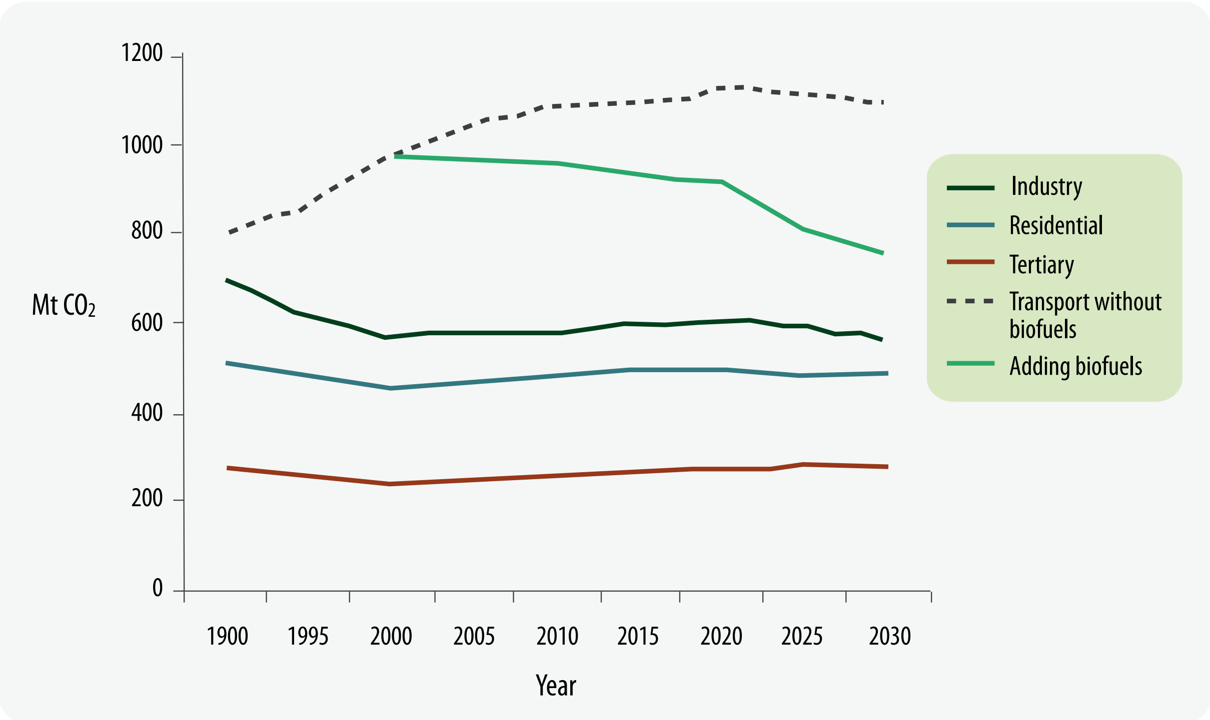


Figure 1.4. *CO_2 emissions (MT), EU25, 1990-2030 (projected), based on: presentation by Hillka Summa, October 2006*

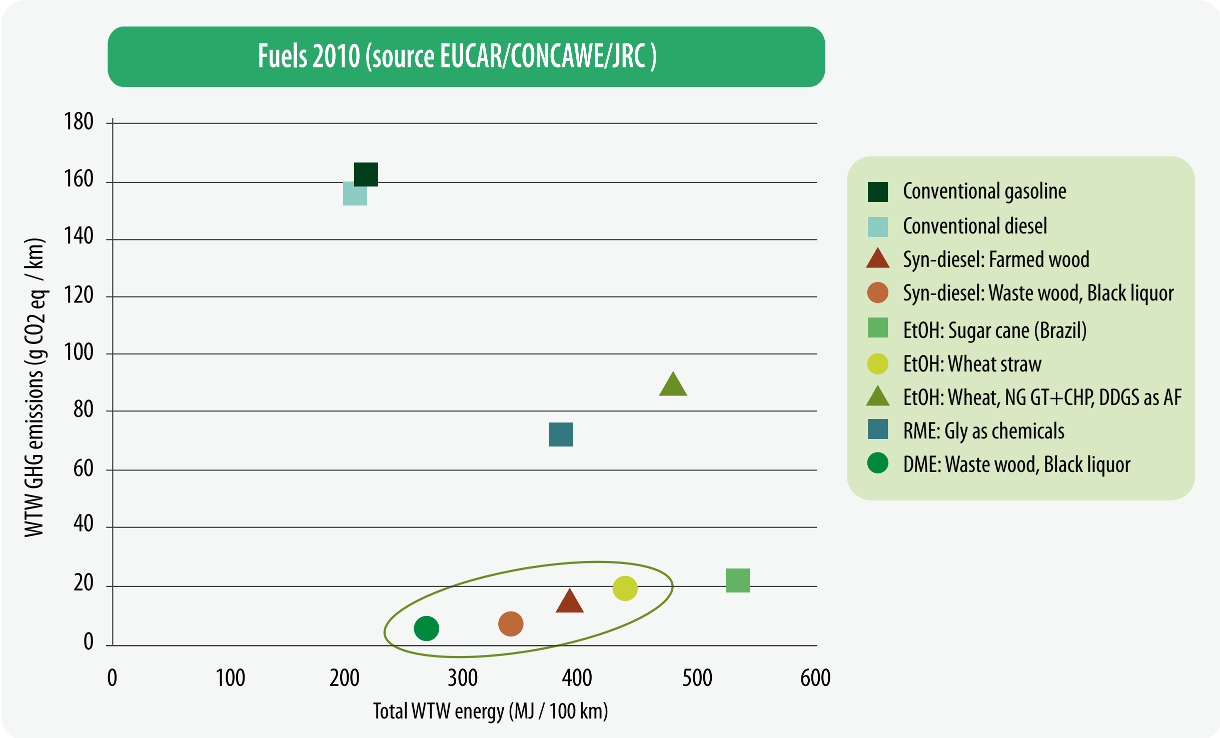


Figure 1.5. *Well-to-wheel greenhouse gas emissions (in CO_2-equivalents/km) versus total energy use for running a mid-size car over a distance of 100 km*

Land capable of producing crops or forest at a rate sufficient to provide biomass for biofuels at an economically viable price on a sustainable basis are limited, both in the EU and worldwide. The rise of agricultural commodity and forest product prices in 2006 and 2007 due to a strong world demand has been also partially attributed to an increasing competition for food, feed, technical and energy uses. Increasing demand from the biofuels sector will require strategies to improve the energy yield per hectare of existing land used for agricultural and forest products. It will also require consideration of increased use of other land resources. The development of high-yield plants with new properties and qualities suited to biofuel production and making use of the whole crop for energy will reduce the pressure on land and help stabilise markets and prices.

Sustainability is a critical issue in the development of biofuels. Unregulated excursions into unsuitable regions, soil types or eco-systems can result in deforestation, erosion and loss of soil structure with associated loss of biodiversity. Adopting the wrong production chains, end-use strategies and legislative background could end up with biofuels that emitted levels of GHG comparable to that of the fossil fuels they replaced. Some types of biofuels can cause increased end-use emissions and hence developments are required both in powertrain design and biofuels quality to ensure this does not happen. Hence, to justify the production and use of biofuels worldwide they must be shown to be sustainable.

Biofuels must perform significantly better, in terms of sustainability, than the fossil fuels they replace. This has to be proven by robust technical, social and economic analysis and also to be socially accepted on a local as well as global level that is applicable both to EU domestic production and imports.

The EU Biofuels Industry - Current Situation and Foresight

Since the start of this millennium the production of biofuels, biodiesel in particular, has significantly increased in the European Union (Figure 1.6) and worldwide. In 2006, the EU biofuel consumption amounted to 5.38 million tons oil equivalent (Mtoe), an increase of 80% in relation to 2005. 3.85 Mtoe were consumed in form of biodiesel, 0.88 Mtoe as bioethanol and 0.65 Mtoe as other biofuels, such as pure vegetable oils and biogas. This represents 1.8% of the total EU transport fuel consumption of 296 Mtoe in relation to1% in 2005[3]. So far Germany, Sweden and Spain produce the most biofuels for transport, but only Germany and Sweden have met the indicative EU target of 2% for 2005.

[3] *EurObserv'Er. May 2007. Biofuels Barometer: p.64.*

In 2006 3.1 million ha or 3% of the total EU 27 arable land were used for the production of biofuels.

The Member States of the European Union are jointly responsible for the past and anticipated future expansion in the use of biofuels. They participate in measures and objectives adopted by the Parliament and Council on the basis of studies, communications, directives and regulations generally initiated by the European Commission. The first significant milestone in the increased production of biofuels was the adoption of the **Directive on the promotion of the use of biofuels or other renewable fuels for transport, 2003/30/EC**. This set two indicative targets: to increase the share of biofuels to 2% in 2005 and to 5.75% in 2010 (energy equivalent).

The first indicative target – 2% by 2005 – was not achieved. At the present time, it appears difficult also to achieve the 2010 target. On this basis the EU, through the European Commission, reviewed its policy and looked beyond 2010 resulting in a proposal for the revision of the biofuels directive, which came up last year within the new energy policy document[4]. This sets a minimum requirement for the share of biofuels in 2020 at 10%. The EC also produced a proposal to do this in 2007[5].

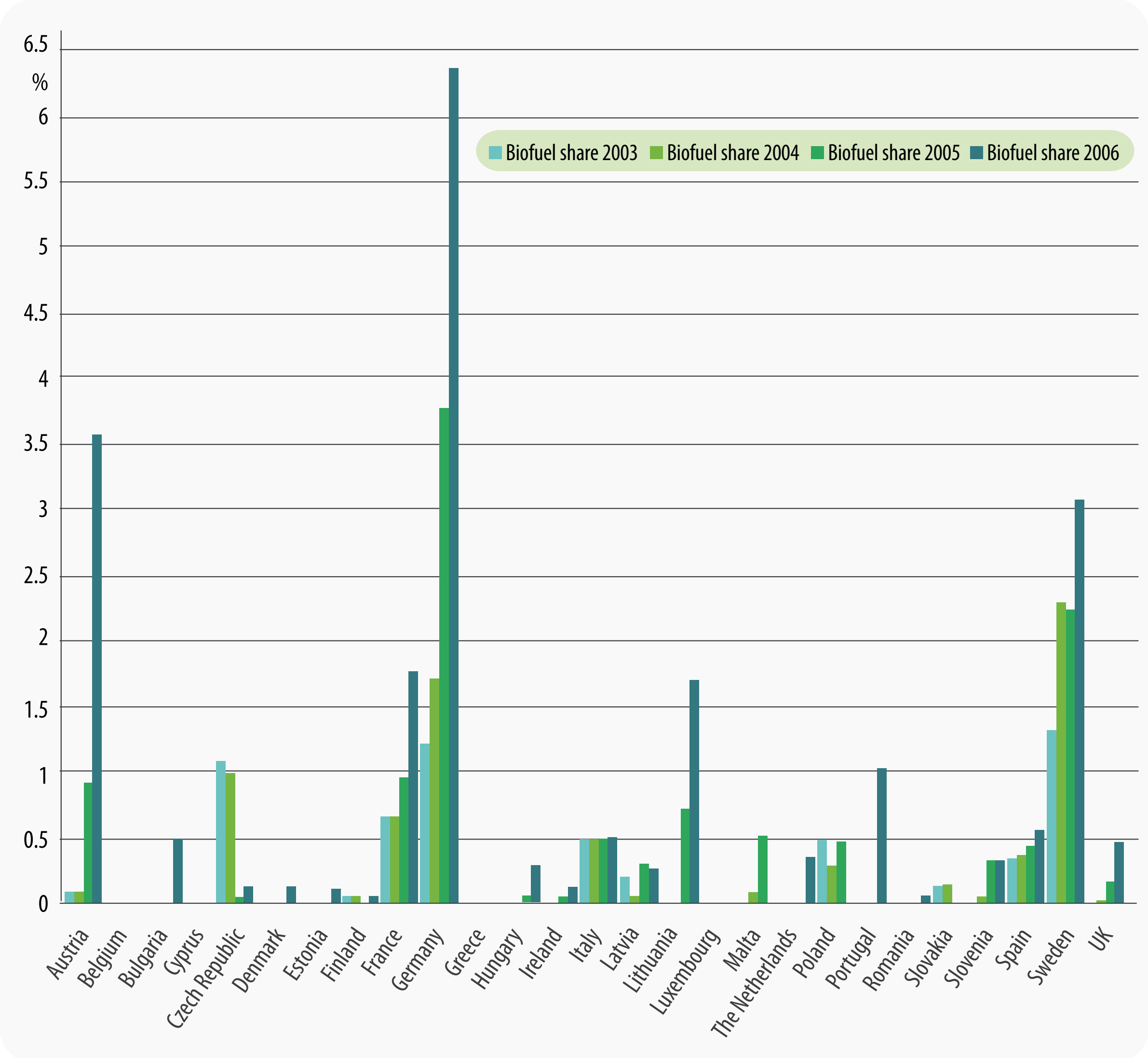


***Figure 1.6.** The share of biofuels for transport in the European Union. Source: European Commission DG TREN, Biofuels Progress Reports provided by Member States (SEC (2007) 12)*

[4] *Integrated Energy and Climate Change Package, published March 2007. http://ec.europa.eu/energy/energy_policy/index_en.htm*

[5] *European Commission. 2007. Biofuels Progress Report. http://ec.europa.eu/energy/energy_policy/doc/07_biofuels_progress_report_en.pdf*

In the longer term, the aim of biofuels development in Europe is to be in a position to implement the BIOFRAC report, with a vision of up to 25% penetration in the road transport fuel market by 2030. Meeting ambitious 2020 and 2030 targets requires the development of improved and new technologies to obtain biofuels in a cost-competitive and sustainable way. Possible biofuel mixes and the impact of these on GHG saving are illustrated in tables 1.1 and 1.2. as presented in a recent scenario study. The final picture in the marketplace in terms of import-export balances, production pathways, costs, etc will be determined by market forces influenced by the regulatory framework in force at that time.

Fuel	More domestic	More imports
EU biodiesel	4	5
EU first-generation bioethanol	13	7
EU BTL	11	7
EU cellulosic ethanol	5	0
Biodiesel (imported rape oil)	3	3
Biodiesel (imported soy/palm oil)	6	9
Imported sugar cane ethanol	1	12
Total (14%)	43 Mtoe	43 Mtoe

***Table 1.1.** Possible biofuel mix for 2020, based on technology development and imports. Based on: SEC(2006) 1721.*

With regard to land and biomass availability, there are considerable differences in the size and vegetation pattern within the 27 Member States of the EU and consequently also in their potential for biomass production. Managed forests dominate the landscape in Northern Europe while there is more arable land in other regions. There are also wide variations in climate between Member States which results in differences in current land use and cropping patterns.

As the importance of biomass feedstocks has increased numerous studies have been carried out, both at the European level and worldwide, in order to assess the theoretical and technical potentials for biomass production. Results provide a wide range of estimates that depend on the assumptions and hypotheses that underline them. If the EU 10% target for 2020 is to be met by domestic biomass, this would require 17.5 million hectares or 15% of the total arable land in the EU. Studies carried out by the DG Agriculture of the EC concluded that this does not overly stretch either land availability or production intensity.[6]

	More domestic	More imports
Extra cost (oil price $48)	€15-17 bn	€11-15 bn
Extra cost (oil price $70)	€10-11 bn	€5-8 bn
Greenhouse gas savings	101Mt CO_2	101Mt CO_2
Oil import savings	43 Mtoe	43 Mtoe

***Table 1.2.** Impact of the biofuel mix shown in Table 1.1 on costs and GHG saving. Based on: SEC(2006) 1721.*

1.5 The Biofuels Chain: Key Issues to Identify Technology Needs

The overall chain of biomass production, conversion to biofuels and end use is complex (figure 1.7) and requires integrated collaboration of many diverse stakeholder groups; farmers, foresters, engineers, chemical companies, fuel distributors, engine designers and vehicle manufacturers. In order to cover this complexity and understand the flow of activities that have to been processed, the chain has been divided into three main technical areas: **biomass production, conversion processes and product end-use**. Aspects of sustainability and environmental impact as well as the market and legal aspects have been considered on the basis that they cut across all technical areas. The composition of the BiofuelsTP workgroups reflected this overview.

The SRA has focused on liquid biofuels (although biogas pathways are indicated also), as liquid fuels are the preferred choice for road transport due to their relatively higher energy density, which affects vehicle autonomy (distance

[6] *European Commission. April 2007. Impact Assessment Renewable Energy Roadmap.*

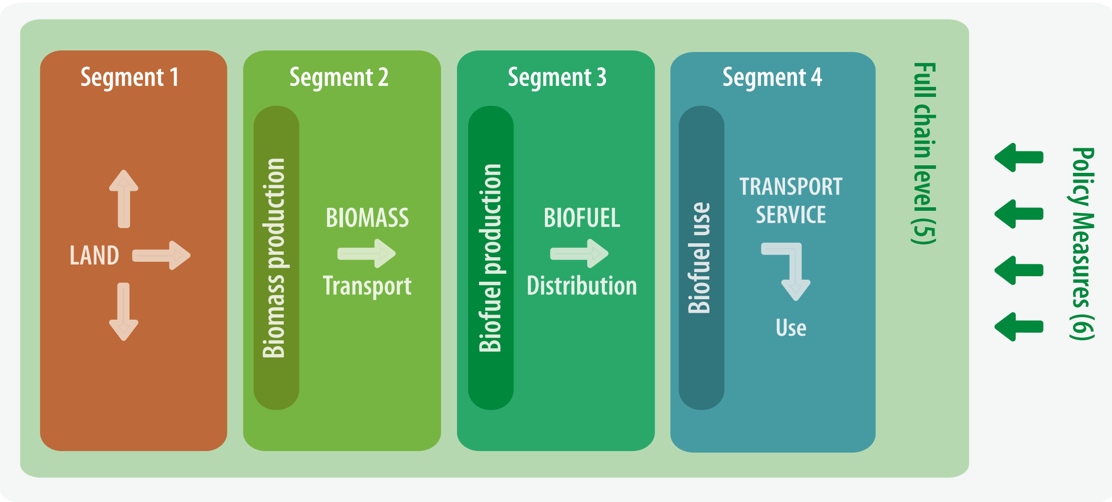


***Figure 1.7.** The biofuel production chain. Source: BiofuelsTP - WG4*

travelled before re-fuelling). CNG requires separated logistic and refuelling systems also. For these reasons, compressed natural gas (CNG) vehicles are expected to find niche applications mainly (e.g. bus fleets). Should CNG vehicles find a higher market share in the future, then **biogas** could become more important as a biofuel for road transport.

Although available data are not always coincident, it seems that production routes for methane gas from biomass (either by digestion or by gasification) may end up being more efficient in terms of GHG savings and fuel production per hectare than other fuels. This is why biogas is seen as a promising energy pathway for heat and power generation and could also widen the road transport biofuels scene as far as CNG vehicles gain market share.

Therefore, research should also pay attention to gaseous biofuels. Many of the R&D&D priorities identified in this SRA are applicable to biogas, as feedstock production issues are largely comparable to those of other advanced liquid biofuels and biogas production can be coupled to other gasification-based options. Additional activities not covered here could focus on biogas-specific aspects of biofuel production technologies and distribution and end-use that would be very much linked with CNG.

1.5.1 Biomass Feedstocks

Biomass is defined as organic matter available on a renewable basis. It includes whole plants, both terrestrial and aquatic, as well as residues, and by-products derived through processing within the forest and agricultural industries as well as animal, municipal and industrial wastes. A wide range of biomass feedstocks of differing origin and composition could be used for production of transport biofuels as new technology is produced.

At present almost all such biofuels are derived from **agricultural crops** that are predominantly produced as food crops. These include sugar crops (sugarcane and sugarbeet), starch crops (such as maize and wheat) and oil crops (such as rapeseed or soy bean). Most of these crops produce agricultural residues that can be derived from field activities after harvesting the main product. These include materials such as straw, prunings, etc. Agriculture also produces large amounts of by-products such as animal manure.

Forest biomass is available from clear-fell harvesting as well as from short-rotation and coppice systems based on fast growing species. Forests also produce biomass in the form of residues from harvest operations that, at present, are mostly left in the forest after stem wood removal.

This includes branches, foliage, roots, etc, as well as thinnings and the products of complementary felling that may occur where maximum sustainable harvest level exceeds the actual harvest required to satisfy immediate round wood demand. European forest resources show a significant potential for increased yield.

It is also possible to increase the use of **'energy crops'** that are bred and cultivated to produce biomass with specific traits that favour their use as an energy vector. Such crops may also be bred to enhance their use in biorefineries where it is anticipated that a wider range of end products, including chemicals and other nonfood bioproducts, may be produced in parallel with fuels.

Large amounts of biomass are also available in the form of biodegradable fractions derived from municipal solid **waste**, sewage, sustainably harvested peat and various industrial and commercial activities.

The availability and quality of land will determine the amount and type of feedstocks produced in EU in the future. Recent studies (EEA (2006)[7], WWF (2006)[8]) indicate that increased bioenergy demand could affect areas of both extensive farming and grasslands reflecting potential shifts from existing food and feed production to bioenergy. This is particularly true for lignocellulosic crops.

The use of low fertility, marginal land has also been studied and may indicate a substantial future potential. However, production on marginal lands has to meet both economic and sustainable criteria in order to become competitive, indicating the need for innovative approaches.

It is also necessary to establish the infrastructure that will enable large quantities of biomass to be delivered to factories taking into account problems that could arise from question of ownership when much is produced on a large number of small farms. Various scenarios and strategies need to be developed for both small and large scale biofuels concepts based on all types of resources; forest, agricultural and waste based. Improving the quality of agricultural lifestyles and finding new pathways that lead to optimised sustainable production will also be a key issue to securing the supply of biomass feedstocks. This includes aspects of optimised water management, cropping strategies, cooperation, etc. Biomass trade flows are also a rapidly increasing reality and as such they need to be considered under a sustainable framework of both production practices and product quality standards.

1.5.2 Converting Biomass to Biofuels

The place of biomass conversion within the overall strategy for producing liquid transport fuels is shown in Figure 1.8 taken from the BIOFRAC Vision Report. This includes a mention of the numerous **conversion processes** to obtain biofuels from biomass. The three main routes from biomass to liquid transport fuels are outlined in the three technology boxes below that cover:

A. The production of biodiesel from oils and fats

B. Biochemical pathways to ethanol

C. The thermochemical routes to liquid biofuels

Current technology mainly involves the production of **biodiesel** from vegetable oils such as rapeseed and the production of ethanol by fermentation of sugar streams either obtained directly from sugarbeet, or through hydrolysis of starch from wheat and other cereals.

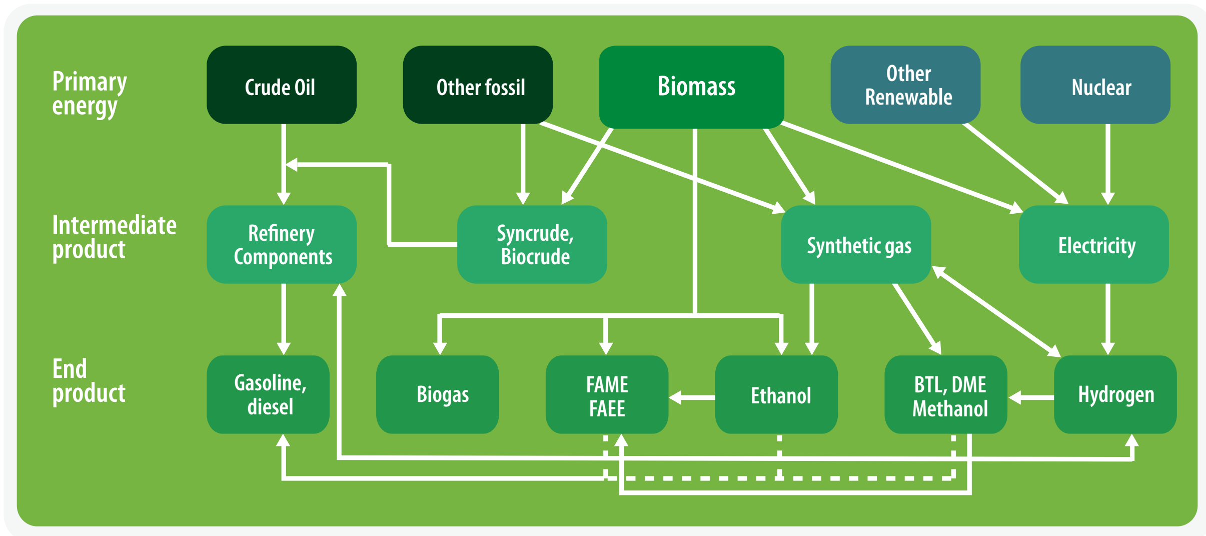
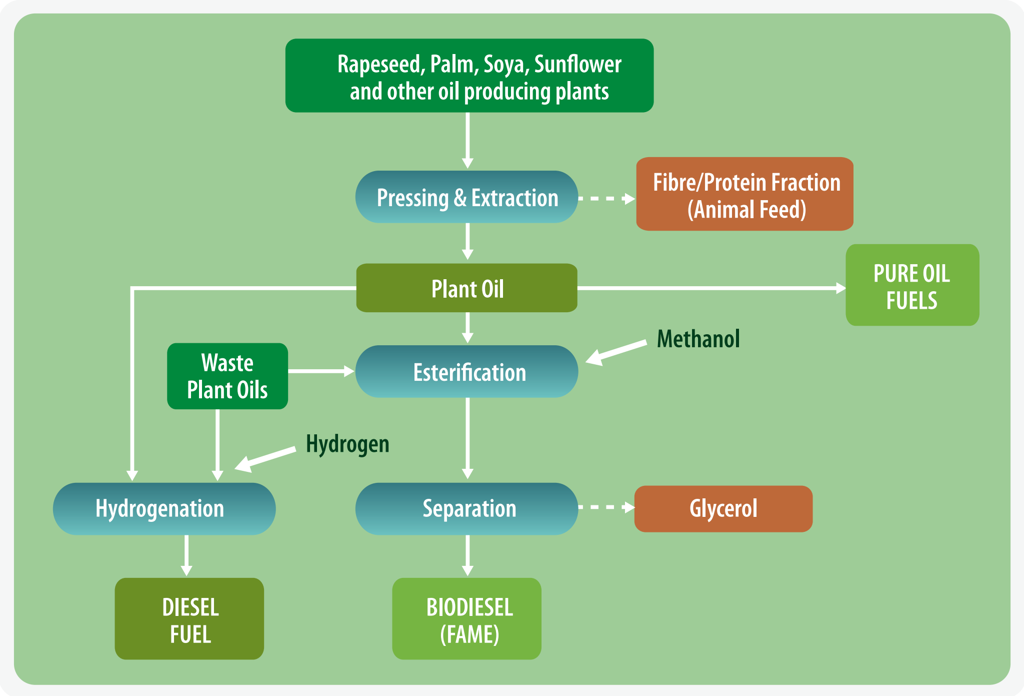


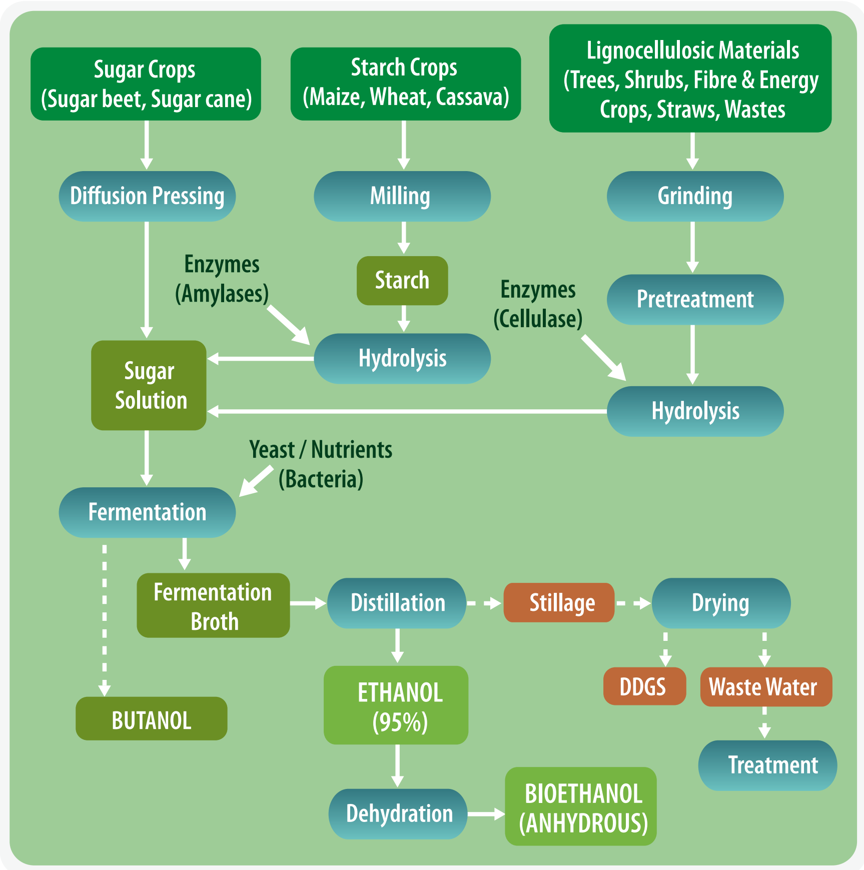
***Figure 1.8.** Conversion processes to obtain biofuels from biomass: Source: Vision Report, 2006*

[7] *European Environment Agency (EEA). 2006. How much bioenergy can Europe produce without harming the environment. No 7/2006*

[8] *WWF/Öko-Institut. 2006. Sustainability Standards for Bioenergy. http://www.wwf.de/fileadmin/fm-wwf/pdf_neu/Sustainability_ Standards_ for_Bioenergy.pdf*



Technology Box A. The production of biofuels from vegetable oils



Technology Box B. The biochemical routes to liquid biofuels

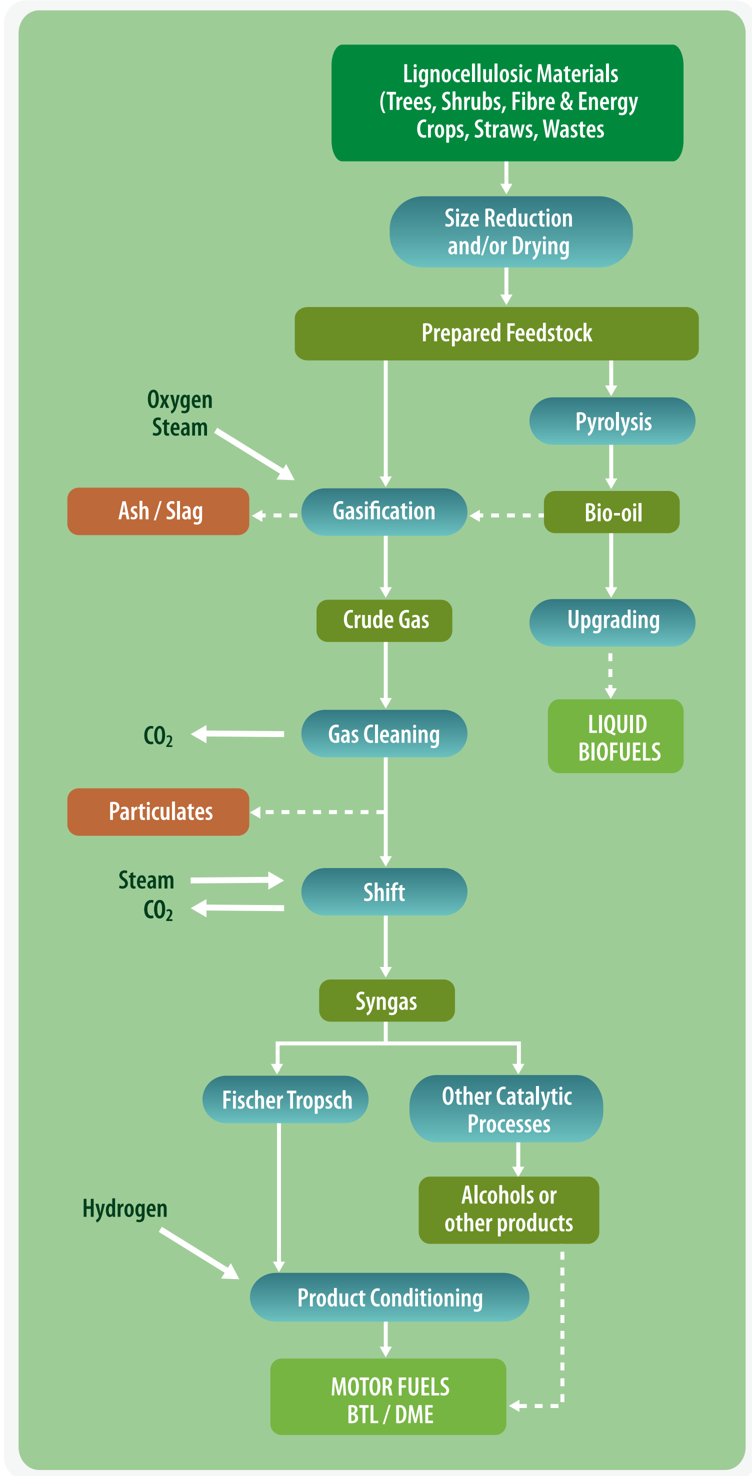
Fats and oils of biological origin are predominantly triacylesters of glycerol (triglycerides). These form the major feedstock for the generation of methylesters in Europe. The methylesters are commonly referred to as biodiesel. The so-called "ester-pathway" (Technology Box A) includes the intensification and evolution of biodiesel-processes and the conversion of triglycerides into other fuels.

The **biochemical pathway** to ethanol (Technology Box B), based on biotechnology, uses enzymatic and fermentative processes for producing biofuels and co-products.

Production of ethanol from sugar and starch is a mature technology generating millions of tonnes per annum. However, technical developments are required in order to generate sugar streams from more widely available raw materials as lignocellulosic biomass in a cost-effective way.

In addition to the development of biological routes for utilisation of lignocellulosic feedstocks considerable potential lies in a number of alternative routes to biofuels based on thermochemical routes (Technology Box C).

The **thermochemical pathway** is characterised by the use of high temperature (500-1500°C) transformations, such as pyrolysis or gasification. It can utilise almost any type of lignocellulosic material as feedstock. Although the basic steps which are required are known, the whole chain required for converting biomass to biofuels needs to be demonstrated and costs reduced.



Technology Box C. The thermochemical routes to liquid biofuels

1.5.3 Using Biofuels for Road Transport

Biofuels need to comply with end-use requirements related to engine-vehicle characteristics. This can be divided into various sectors on the basis of engine type (spark ignition or compression ignition, which in turn determines the fuel used as gasoline or diesel respectively) and engine size (grouped as cars and light vans normally referred as "passenger cars", or as lorries, buses and similar vehicles of over 6 tons unloaded weight, normally referred as "commercial vehicles").

Engine and fuel requirements are summarised below in two forms; one covering the type of engines (powertrains) used and the other covering the resultant fuel mixture that will be required as a consequence. Current as well as new technologies are considered in consistency with the timeframe for biofuels development till 2030.

Present Status

a) Diesel Engines

Diesel vehicles have gained an **increased market share** in the sector of passenger cars during the last decade. They remain the main type of powertrain for commercial vehicles.

Fuel Specification: The current European fuel specification for diesel fuel EN590 allows the blending of up to 5 vol.-% of biodiesel (B5) to fossil diesel. Biodiesel used for blending has to meet specification EN14214 which is the standard for neat biodiesel distributed in Europe. Biodiesel offered in Europe is mainly based on Rape Seed Oil Methyl Ester. However, other biomass sources (Soy Bean Oil, Palm Oil, Sunflower Oil) are increasingly used as are waste cooking oils in limited quantities.

Fuel Availability: Blends from 2 to 5 vol.-% biodiesel are offered in several European countries. Due to a mandatory total biofuel share of 4.4% (on energy base) in Germany EN590 diesel mainly contains 5 vol.-% of biodiesel (B5). German biofuel share targets adopted for 2009 require a further increase of biofuel blending to diesel to over 5 vol.%. B7 and so-called "B7+3" which stands for 7% of biodiesel and 3% of hydrogenated vegetable oil (HVO) blended to fossil diesel are discussed as future options in Germany. However short-term availability of HVO will be very limited. B30 (30% of EN14214 biodiesel blended in diesel) for captive fleets is offered in certain countries like France and the UK. Neat biodiesel (B100) is mainly offered in Germany, which has a well developed market for B100 counting 1900 filling stations in 2005 offering this type of fuel. B100 is mainly used in commercial vehicles. However, due to stepwise reduction of tax incentives, which started already in 2006, the market for B100 currently suffers a severe decrease.

Vehicle Technology: B5 fuel is approved by all car manufacturers for vehicles of existing fleet and new cars. No adaptation of vehicle parts and engine are required. By contrast, for usage of B100 (neat biodiesel) vehicle adaptation is needed. The vehicle fuel supplying system has to be provided with biodiesel compatible materials. Oil change intervals have to be reduced to counteract accelerated oil aging and dilution with fuel. Even B10 fuel makes certain vehicle and engine adaptations necessary.

In the case of commercial vehicles B100 approved vehicles already meeting Euro5 emission standard are offered by some car manufacturers. B100 approved passenger cars were offered in the past for Euro3 and previous emission standards. Euro4 diesel vehicles generally provided with a particulate filter are not approved for B100 mainly due to occurrence of severe engine oil dilution with fuel during the regenerating modes of the particulate filter.

b) Gasoline Vehicles

Gasoline vehicles currently cover a share of about 50% of all passenger cars in the market. The main biofuels currently introduced in the European market are ethanol and ETBE as a derivative of ethanol. ETBE (Ethyl ter-butyl Ether) is just partly a biofuel, since the butyl part of the molecule is derived from fossil fuel sources.

Fuel Specification and Availability: The current gasoline fuel specification EN228 allows a blending of 5 vol.-% of ethanol (E5) or 15 vol.-% of ETBE to gasoline. An update of the European Fuel Quality Directive (FQD - 98/70/EC) to allow an ethanol blending of 10 vol.-% is under discussion. All filling stations in Sweden and Germany already offer E5. In several European countries ETBE is blended to gasoline.

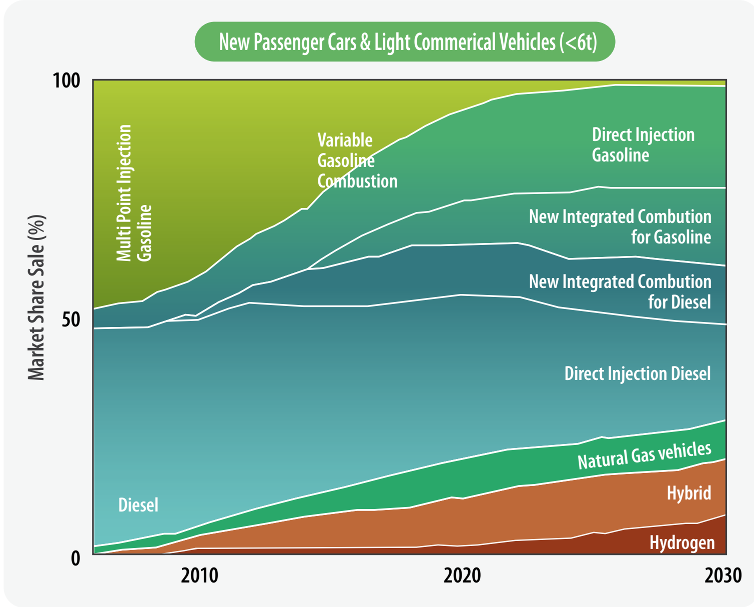


Figure 1.9. Anticipated share of passenger cars and light commercial vehicles (<6t) for various powertrains to 2030. Source: based on EUCAR

E85 fuel (blend of 85% ethanol+15% gasoline) is widely available in Sweden, being introduced in France, and under discussion in Spain and Germany.

Vehicle Technology: E5 according to EN228 standard is approved by car manufacturers for all vehicles of the existing fleet and new cars. No adaptation of vehicle components or engine is required. E10 fuel is compatible to most of the fleet vehicles except some DI gasoline vehicles with first generation fuel injection systems provided with rails made of aluminium.

The use of E85 requires adaptations of materials of the fuel supplying system and the engine. This is due to the corrosive impact of ethanol and its worse cold starting properties compared to gasoline. A number of car manufacturers offer Flex Fuel Vehicles approved for usage of E85, neat gasoline, and any mixtures thereof, mainly on the Swedish market and few models on the French and German market.

Roadmaps up to 2030

a) Powertrain roadmaps

The expected trend for the different types of powertrains for passenger cars and light commercial vehicles according to a EUCAR study[9] is shown in Figure 1.9. It is predicted that **gasoline and diesel engines will remain the dominating powertrains until 2030**. New combustion schemes, such as HCCI (Homogeneous Charge Compression Ignition) will be introduced gaining an increasing share. However, it is expected that the market share of hybrid vehicles (with both gasoline and diesel engines) will remain significantly lower compared to diesel and gasoline vehicles until 2030 as will the market share of gas and hydrogen propulsion vehicles. Liquid Petroleum Gasoline (LPG) vehicles are not expected to have a significant market share in 2030.

The trend foreseen for different types of powertrains that will be applied in commercial vehicles is shown in Figure 1.10.

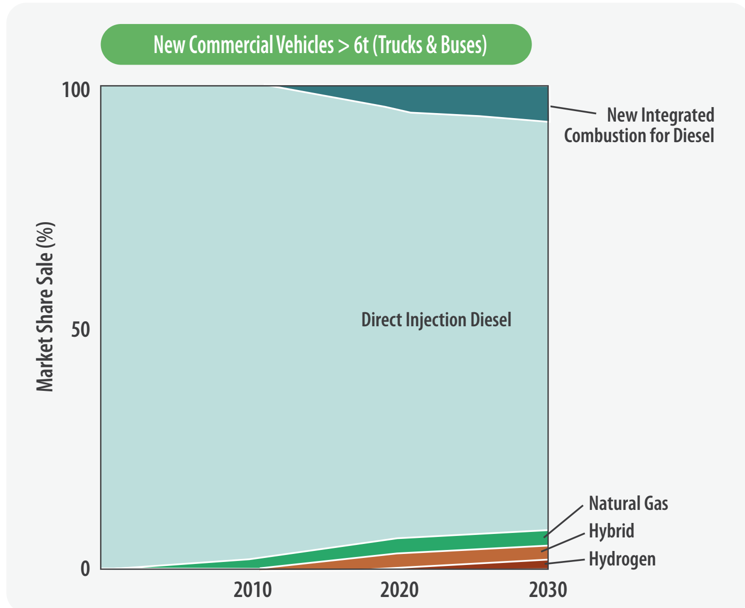


Figure 1.10. Main technology trends and share of engines in Europe for commercial vehicles: Source: MAN

[9] *Eucar, Concawe, JRC. May 2006. Well-to-Wheels analysis of future automotive fuels and powertrains in the European context,Version 2b.*

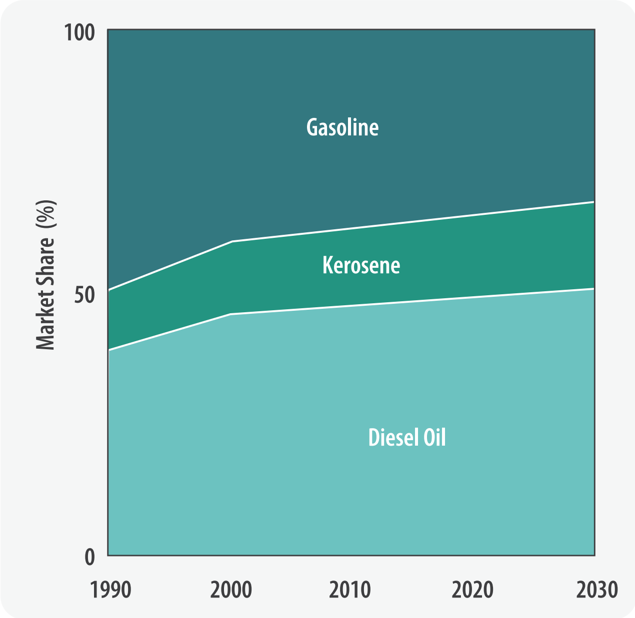


***Figure 1.11.** Share of types of fuels in the European Market to 2030. Source: EC 2003.*

This suggests that diesel engines will remain the major powertrain for commercial vehicles. New integrated combustion schemes (e.g. HCCI) will be introduced, but will only account for a small share. Other types of powertrains (e.g. CNG, H_2, DME) will only find niche applications and will not be significant in terms of the overall picture of fuel use.

b) Fuel Roadmap

The fuel demand will reflect the development of the entire vehicle fleet, since future demand for transport fuels will reflect both the introduction of new vehicles and mix of share of powertrains of older vehicles still running at any particular time. This makes it difficult to predict exactly the composition of future road transport fleets since the average lifetime of vehicles is affected by many factors and may change in future as changes are made in aspects such as car tax, fuel type, parking and congestion charges, introduced in order to encourage purchase and use of vehicles with lower emissions of GHG.

According to the forecast[10] shown in Figure 1.11, the transport sector will show **an increase in the use of diesel fuel** and a relative decrease in the use of gasoline fuel up to 2030. The use of kerosene for aviation is expected to show only a slight increase during the same period. A significant increase in fuel demand is expected for trucks. Use in this sector in 2030 is expected to be twice that of 1990. However, only a moderate increase in fuel demand is expected for passenger cars over the same period (Figure 1. 12).

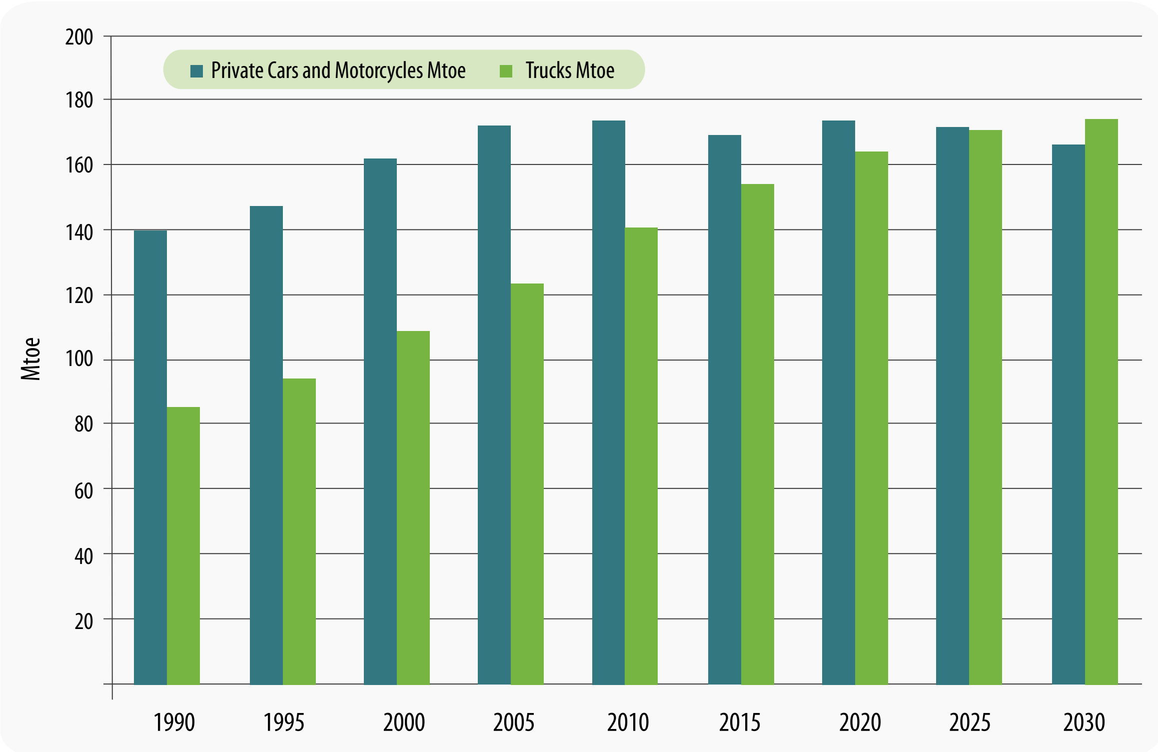


***Figure 1.12.** Fuel Demand by Vehicle Type in the EU27 (until 2030). Source: EC 2003*

[10] *European Commission, DG Energy and Transport. 2003 - Update 2005. European Energy and Transport Trends to 2030.*

It should be noted that at present there is a surplus production of gasoline in Europe. This is currently exported to the USA, a market that is expected to be covered in the future by increased local production in a higher extent than today. This would lead to a further increased surplus production of gasoline in Europe.

Kerosene will continue to be mainly consumed in aviation. However, it may also be an option to use it as blending component in conventional diesel or gasoline fuel in order to adapt fuel characteristics to future requirements.

Based on the fuel demand described above and other sources, a biofuel roadmap was produced by workgroup 3 of the BiofuelsTP (Figure 1.13). Information sources taken into account in deriving this figure included the anticipated indicative target (on an energy basis) for 2010 of 5.75% by EU-Directive 2003/30/EC[11], for 2020[12] of 10% that is expected to become a mandatory target; and for 2030 the BIOFRAC vision of up to 25%.[13]

In developing this roadmap it was assumed that a significant part of biofuels would be targeted at diesel engines in order to help cover the increasing demand of diesel fuel in Europe and reduce the surplus production of gasoline fuel. The assumption was that 75% of the biofuel availability would be fuel for diesel engines and 25% fuel for gasoline engines. It is evident that this view is strongly fuel demand driven.

Different figures could result depending on factors such as future biomass availability, success of different conversion technologies and higher biofuel blends, etc.

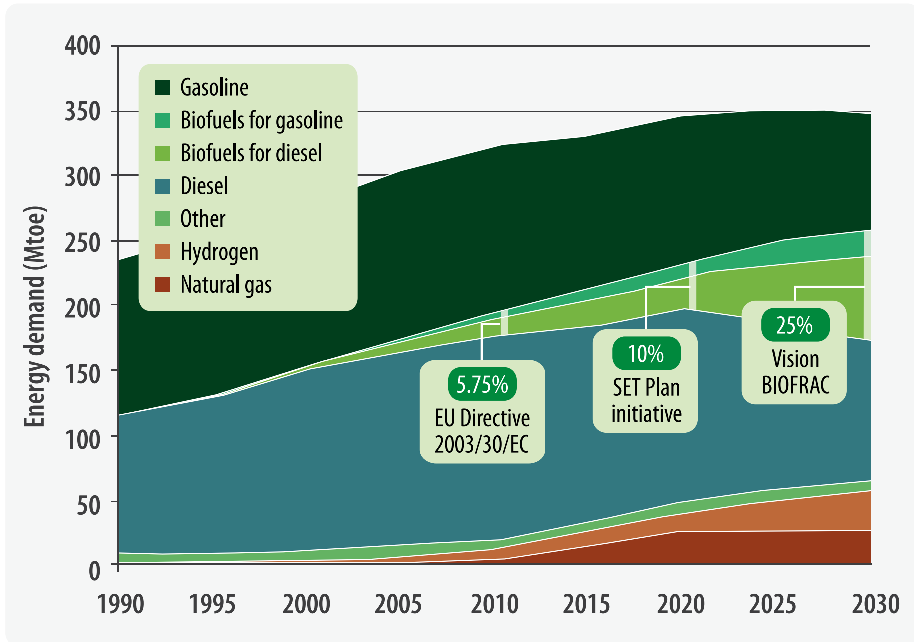


***Figure 1.13.** Fuel Roadmap for Transport Source: BiofuelsTP – WG3*

[11] *EU-Directive 2003/30/EC, http://ec.europa.eu/energy/res/legislation/doc/biofuels/en_final.pdf*
[12] *SET-Plan initiative 2007*
[13] *Biofrac. 2006*

2. R&D&D PRIORITIES AND ROADMAPS

This section of the SRA covers the research priorities that have been identified through the activities of the five workgroups of the BiofuelsTP. The results are presented in such a way that they follow the production chain, starting with biomass resources and then conversion technologies, followed by aspects of distribution and end-use. Finally, R&D&D needs related to the cross-cutting topic of biofuels sustainability are identified.

R&D&D priorities have been classified as short-medium-long term with reference to the time horizon at which the R&D&D results would be needed in order to achieve the biofuels targets (more than 5.75% by 2013, 10% by 2020, up to 25% by 2030). The timeframe is also related to the maturity of technologies, as developments of more mature technologies are likely to be implemented in the shorter term while newer technologies will require more time to deliver.

2.1. Availability and Supply of Biomass Resources

The availability of biomass can be increased by optimising production systems (yields, system efficiency, etc) and broadening the feedstock types as well as by making better use of existing resources taking into account both demand and supply issues. The views expressed in this report are further complemented by those of other European Technology Platforms as indicated in the box below.

In setting R&D&D priorities it is stressed that future biomass feedstocks should meet a full range of sustainability criteria irrespective of whether they are grown in Europe or are imported.

Carbon contained in biomass may be considered as recycled, as it is captured from the atmosphere through photosynthesis. Therefore when it is released as CO_2 as a result of biofuel combustion the overall process can be considered in principle to be CO_2 neutral. In practice, a certain level of net CO_2 emissions are still produced due to the use of fossil fuel during biomass production, conversion to biofuel and for the subsequent transport of the biofuel for delivery to the consumer.

If during the process of biomass conversion, CO_2 which is emitted is recovered, collected and permanently stored (the so-called carbon capture and sequestration, or CCS), the overall CO_2 balance would be even more favourable.

Various options can be considered for CCS, but at present underground storage is considered as the most readily available option. Application of CCS could result in biofuel production systems with an overall negative carbon balance, resulting in a net extraction of CO_2 from the atmosphere. However, at present it is difficult for economic reasons to implement such an option since logistics for collecting, transporting and injecting CO_2 underground are not yet in place. This is therefore a longer term option which deserves further evaluation and research.

In addition to CCS land use changes associated with biofuel production can also result in net CO_2 sequestration or emission due to changes in the level of organic carbon in soil. For example the diversion of land used to produce annual food crops to production of perennial woody crops for 2nd generation biofuels will result in a gradual increase in soil organic carbon content until new equilibrium is reached as a result CO_2 is sequestered in the soil. On the other hand, permanent woodlands or pastures with high soil carbon concentrations act as net CO_2 emitters when converted to crop land.

2.1.1. Agricultural Crop Residues

Small grain cereals (i.e. wheat, barley, triticale, rye, oats, rice) dominate the EU arable land covering around 40% of the area in the EU27. As a result cereal straws are the main crop residues generated. However its energy potential is limited as much is already used for animal feeding, bedding, etc, while the high ash content is of concern during combustion. Corn is also a significant arable crop currently grown on around 10 million ha in EU27.

Oilseeds (rapeseed and sunflower) cover almost 8.4 million ha in EU27 while grapevines and olive trees use 3.8 and 2.3 million ha, respectively. In additions to cereal straws agriculture produces other lignocellulosic feedstocks such as mowings from set aside and natural habitats. It should be noted that the bulk of European arable production is mainly in France, Germany, Spain, Poland, Italy, UK, Bulgaria and Romania, reflecting size and intensity of the agricultural sector in these Member States.

Currently most residues are used in small to medium scale applications especially in the agro-industrial sector where feedstocks are processed on site and further exploited for either heat or combined heat&power. Denmark is a key example of straw utilisation for energy covering the 'supply chain concept' for small to medium scale applications.

Complementary Technology Platforms

Actions required to increase the availability and quality of plants and plant products have also been considered by the following Technology Platforms.

European Technology Platform 'Plants for the Future'

This TP has set a vision and a strategic research agenda for European plant biotechnology and genomics research that includes a number of challenges for society, strategic goals contributing to address these challenges and a road map to meet these. They address the potential contributions of new technologies to healthy, safe and sufficient food and feed; to plant-based products – chemicals and energy; to sustainable agriculture, forestry and landscape; to vibrant and competitive basic research; and to consumer choice and governance.

The SRA includes a section that focuses on non-food plant uses (Challenge 2: Plant-based products - chemicals and energy). This has three main goals, for which they suggest key actions required within a 5, 10 and 25 year timeframe. The goals relate to:

1. Biochemical production
2. Bioenergy production
3. Enabling research for plant-based products.

Goal 2 is of direct relevance to the production of biofuels, while goal 1 and 3 are important for the development of biorefineries.

Further information: **www.epsoweb.org/Catalog/TP/index.htm**

European Forest-Based Sector Technology Platform

This TP has also produced a vision document and SRA aiming to further the development of innovative products and services that use wood and can further contribute to mitigate climate both by 'locking up' carbon and replacing products based on fossil resources.

It considers ways in which wood can contribute to the economy by providing substitutes for non-renewable materials in sectors such as packaging, fuels, chemicals and construction.

While the forest already represents the major source of biomass energy, the TP expects this sector to enhance its role with industrial activities based on bio-energy conversion forming the third pillar of the forest industry - along with the traditional use by the paper industry and the woodworking industry - as Europe reduces its dependence on oil with the production of advanced transportation bio-fuels.

The SRA highlights the need for research in this area dealing with the direct conversion of forest derived raw materials into advanced bio-fuels with feed stock mainly coming directly from forests, tree plantations and manufacturing residues.

In more detail, topics covered range from the fullscale realisation of the zero-waste biorefinery concept for the production of bio-fuels alongside chemical pulp production to the gasification of pulping spent-liquor to produce methanol/dimethyl-ether, which can be used as a vehicle fuel.

Further information: **www.forestplatform.org**

Progress Required in Utilising Agricultural Residues

Using the various streams of residues as raw material for biofuels is not currently at commercial level. As conversion technology is developed, careful assessment of both the feedstock types and their fuel properties as well as development of the logistics and the related infrastructure to handle bulk and heterogeneous material will be required. Within the EU27 agricultural residues are characterised by their diverse nature and a marked regional distribution. This could restrict their use unless effective logistics are developed to enable them to be supplied in bulk as required by industry while minimising costs per unit.

R&D&D Short term (up to year 2013)

Develop integrated approaches for regional forecasts of availability by combining top-down and bottom-up approaches, including externalities (potential reductions in GHG emissions, land use changes, imports, interactions of different markets, policies, etc).

R&D&D Medium term (up to year 2020)

Investigate biomass supply systems (including the use of residual and waste feedstocks) covering the issues of biomass production, harvesting/collection/sorting and logistics to meet the conversion requirements. Demonstrate a portfolio of systems, based on Best Available Technologies, subject to considerations of regional ecology and climate showing a high potential for feedstock supply including benchmarking of agrobiomass and forestry chains.

R&D&D Long term (up to year 2030 and beyond)

Develop feedstock quality data (physical and chemical) both for dry and wet biomass in relation to diverse end use options and post harvest operations such as size reduction, densification, blending, etc. In addition develop physical and chemical pre-processing methods (including blending and fractionation), systems and strategies to provide homogeneous feedstock for large scale applications thus meeting the quality requirements of the conversion technologies.

2.1.2. Forest Biomass

Forests represent the largest potential biomass resource, though their use is dependent on the development of 'lignocellulosic conversion technology' and competition for this resource with conventional forest industries as well as with 'wood to energy' systems generating heat and power. The forest industry is well advanced in terms of both the production and handling of biomass as well as to the extent to which it consumes biomass to cover its energy needs. For instance the European paper and pulp sector covers 50% of the industry's total primary annual energy consumption with biomass-based fuels[14].

Progress Required in Forestry

As the concept of biomass energy exploitation shifts in new directions and innovative technologies are introduced, forest biomass infrastructures are facing new challenges both in expanding their total yields (through new tree varieties and advanced forest management practices) and in optimising logistics towards supplying new industries, including biofuels and bio-refineries.

[14] *http://www.cepi.org, http://www.cepi.org/Objects/1/files/070129IssueBioEnergy.pdf*

The key elements to achieve progress in this field are to develop biomass cost-supply curves as function of the entire supply system (incl. pre-treatment and storage), time and prices at national level as well as to develop efficient logistic practices for different concepts and at different scales in order to meet the biofuel industry demand. These systems could be benchmarked with Best Available Technologies from the Scandinavian CHP sector.

R&D&D Short term (up to year 2013)

Develop cost-supply curves for forest residues in the EU Member States producing significant quantities of wood. Identify the best available harvesting chains for logging residues and thinnings from forest to mill, including harvesting, chipping, transportation and storing based on existing technologies and so establish the costs and availability of forest chips at mill in each country as a function of average transportation distance. In addition produce similar supply curves for the availability at the mill of other forest-derived materials (bark, other residues, thinnings, etc).

R&D&D Medium term R&D (up to year 2020)

Investigate possibilities of new technology and silvicultural practices in order to decrease costs and increase the supply through identification of technical advances (new equipment, new supply chains) in harvesting, logistics and improvement of silvicultural practices to increase the yield in a sustainable way.

R&D&D Long term (up to year 2030 and beyond)

Investigate the potential for imported biomass or biofuels derived from wood from areas such as Russia, the Americas and Asia and identify feasible business concepts and practices. Develop new trees and other plant species chosen as energy and/or fibre sources, including plantations connected to biorefineries. Look at the climate change implications as forests increase in importance as carbon sinks.

2.1.3. Energy Crops

"Energy crops" may be defined as traditional or new species (tree/ plant) specifically bred and cultivated to fit specific energy needs. Research efforts over the last fifteen years have focused in the selection of plant/ tree varieties, annual or perennial and evaluation of their adaptation, yielding potentials and quality characteristics under different soil-climatic conditions. Today, the main energy-related crop species include:

- **Oilseed crops** such as rapeseed, sunflower, soy, palm, jatropha, etc for biodiesel.
- **Sugar crops** such as sugarbeet and sweet sorghum for bioethanol.
- **Starch crops** such as cereals, corn, potatoes for bioethanol.
- **Lignocellulosic crops** such as Miscanthus, SRC willow and poplar, reed canary grass, switchgrass, fiber sorghum, etc as substrates for heat and power generation.

Progress Required in Developing Energy Crops

Previous studies on energy crops have focused to some extent on the raw material issues (productivity, adaptation, inputs and culture practices). The supply chain concept has been addressed to a lesser extent in EU research projects. Hence, it is suggested that R&D&D should be targeted as follows:

- Maximisation of yield and crop resistance to biotic and abiotic factors (pests, diseases, water scarcity, rising temperatures, etc).
- Initiate innovative cropping systems to allow efficient, bulk material production for food, feed, fibre and fuel (4F agricultural systems).
- Exploitation of marginal land options.

R&D&D Short term (up to year 2013)
Aim to optimise production and management practices and associated equipment to meet conversion requirements continuing to develop integrated solutions for energy and other products in 4F agriculture. The range of feedstocks investigated should be broad covering both agriculture and forestry options, and including both field and laboratory experiments.

R&D&D Medium term (up to year 2020)
In the medium term plant breeding in order to increase yield and crop production efficiency (minimal input / maximal output) as well as yield stability in different environments and energy plant rotation systems is essential. There is also a need to develop innovative cropping systems with the aim of increasing land use options thus minimising the negative impacts from climate change and current intensive land use systems. This could include double cropping and multifunctional land use as well as innovative concepts exploring issues such as: the potential of marginal land and low input systems requiring less water and chemicals, the potential of aquatic biomass (algae), etc.

Forest management systems should be optimised for simultaneous production of biomass for bioenergy and round wood for traditional forest industry. Feedstocks coverage should be broad (forestry, agriculture and wastes; dedicated crops as miscanthus, cardoon, giant reed, switchgrass and SRC; aquatic biomass, etc).

R&D&D Long term (up to year 2030 and beyond)
Develop plant/ tree varieties (breeding and physiology) and optimise management practices. Research efforts should cover both conventional and new crops (from cereals, to non- food crops such as grasses, SRC, annual species as well as new species including algae). Collaboration between the EU and other regions (e.g. USA; Latin America; Asia, etc) should increase. Field and lab experiments are foreseen.

2.1.4. Biowaste Streams

Current primary focus for biowastes is on their safe disposal, so their energy exploitation is a priori advantageous under the following conditions:

- No increase in the release of air pollutants.
- No release of other hazardous substances.
- No incentive is created to increase the production of waste due to it obtaining an economic value as feedstock for biofuels.
- Their Well-to-Wheel energy and GHG emission balance are positive.
- If possible, pathways that combine energy production and material use should be preferred.

Progress Required

One of the most significant problems for the conversion of waste into biofuels is the heterogeneous character of waste, as well as the variability from collection to collection, particularly in the case of municipal solid waste.

The development of separate collection systems, sorting, pre-treatment or even conversion technologies that can deal with an inhomogeneous feedstock flow is thus a necessity for the use of waste as biofuels. Apart from this, there are some waste streams available that can easily be used already today for producing biofuels as they only need to be collected (such as used frying oil, animal fats, etc).

R&D&D Short term (up to year 2013)
There is a need to develop reliable cost-resource curves for the main biowaste streams in Europe. Even though most waste streams can be considered to have zero or negative costs (a fact that may change once there is a demand created), there are costs of collection and potentially additional transport costs etc.

R&D&D Medium term (up to year 2020)
Continued development of waste-based biomass supply systems (incl. residual and waste feedstocks) covering the issues of collection/ sorting and logistics to meet the conversion requirements.

R&D&D Long term (up to year 2030 and beyond)
Integrate biowastes into existing and future supply systems feeding new conversion systems in combination with purpose produced feedstocks to improve conversion efficiencies.

2.1.5 Interfacing Systems Approach

The discussion on future biomass supply implies a complex analysis of the local natural and agroenvironmental conditions, the development of food, feed and fiber demand, development of energy and transport demand and the development of international trade, the latter again being influenced by a number of factors.

Progress Required

There is no single model that is able to address these issues simultaneously. Coupled resource-energy models that can operate on a local as well as global scale, including trade among different world regions, would thus be valuable tools. Such models would need to be able to reflect the effect of policy decisions (e.g. possible development of the CAP; WTO regime; biofuel support policies).

R&D&D Short term (up to year 2013)
Identify and benchmark supply system tools taking into account various land use and market interdependencies, transport, international trade, etc.

R&D&D Medium term (up to year 2020)
System analysis on the supply and demand of biomass feedstocks and the impacts of policy and legislative mechanisms (national, EU27, global level)

Long term (up to year 2030 and beyond)
Define & evaluate the synergies/ conflicts of bioenergy production and environmental protection management.

2.1.6 R&D&D Roadmap

R&D&D needs on biomass resources identified above are visualised in Figure 2.1 with indication of the main R&D&D activities or areas, their time frame and key development or implementation milestones when appropriate.

2.2 Conversion Processes

The priority is to develop processes that are capable of transforming a wide variety of biomass resources into biofuels. Such systems will also include waste biomass (e.g. agricultural residues) as a feedstock, in order to improve the overall productivity by using the whole plant. This potentially widens the range of feedstock that can be used alongside dedicated energy crops such as short rotation crops.

Innovative processes and technologies emerging from EU R&D&D programmes have to be competitive on a global basis, in order to place the European Industry at a forefront position of biofuels technology. In defining R&D&D programmes in the area of biomass conversion processes, it is strongly felt that an integrated approach should be considered in parallel to the individual technology focus in each area or pathway. This is specifically addressed in the biorefinery concepts.

In addition to the continued improvement of currently available conversion processes, new developments will also help to create the market for lignocellulosic biomass derived biofuels. The industry must ensure that smooth transitions occur from current generation to next generation technologies and that both generations of technology become integrated and additive to achieving the expansion goals.

2.2.1 Goals and Targets

The biofuels landscape is extremely broad in terms of its various elements of input (feedstock), process ('hardware & software') and output (fuels & co-products). This creates an inherent level of complexity when attempting to define needs, goals and objectives and potential solutions. For this reason, each area of technology is discussed separately in the following sections of the document.

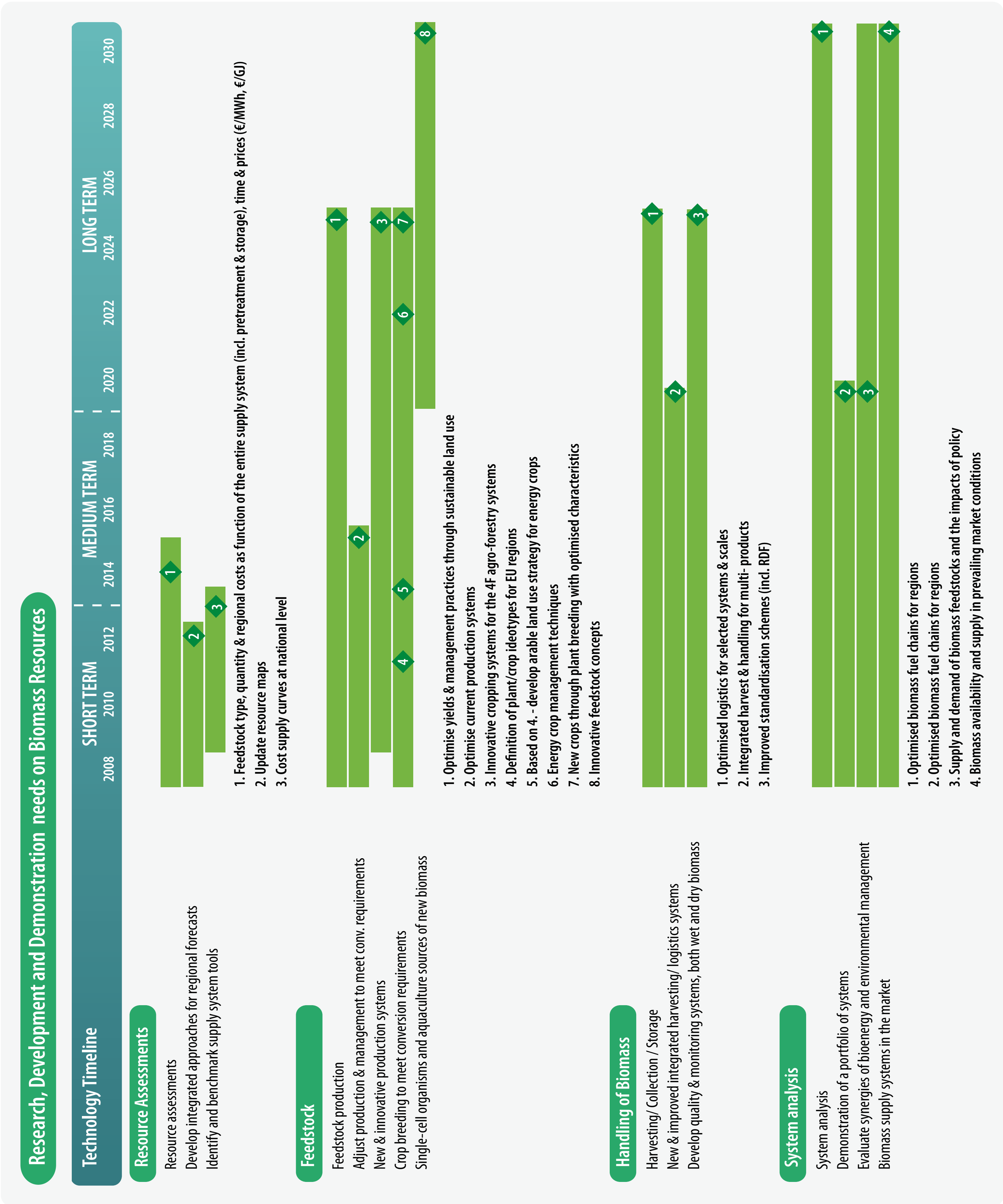


***Figure 2.1.** R&D&D needs on biomass resources*

The long-term goal is to implement the vision report, with up to 25% biofuels penetration share year 2030. This means that new technologies have to be developed, which are able to convert new feedstock sources (i.e. lignocellulosic biomass, energy crops) into biofuels in a competitive way. To reach the high level of penetration into the transport fuels market new biofuels must be capable of being blended with existing gasoline and diesel fuels. Gaseous fuels, which may have more limited markets, are not excluded and may present specific advantages.

In the long term, biofuels need to be produced at a cost which is not higher than fossil fuels to keep the biofuels competitive. The cost of biofuels derived from lignocellulosic biomass needs to decrease by a factor of around 2 from the prices calculated today to become competitive in the future.

As a general rule, it will be necessary to replace (or improve) processes with a relatively low carbon efficiency (less than 30% of carbon emission savings) by more carbon efficient processes (more than 70% of carbon emissions savings) in order to effectively meet the ambitious GHG emission targets.

2.2.2 Feedstock

Feedstock availability is critical for biofuel development. Production, distribution, conditioning and pretreatment steps need to be fully developed in order to facilitate the use of biofuels, as discussed in Chapter 2.1. From the viewpoint of pre-treatment step within the production process, the best way to reduce logistic costs and to meet the production process requirements have to be identified. There is a need for:

- Development of standardisation and quality assurance procedures.
- Development of cost efficient logistics and storage (seasonal and other).
- Adaptation of conventional pre-treatment methods and equipment e.g. drying, size control and classification.
- Development/demonstration of unconventional and fuel specific pre-treatment operations e.g. torrefaction or pyrolysis.

2.2.3. Conversion Technologies

2.2.3 A. Biodiesel Production from Vegetable Oils and Fats

Future biodiesel processes in Europe will be developed using a wider range of renewable oil feedstock. New developments and process improvements will be driven by rising biodiesel demand. The limited amount of land available in Europe would suggest the need for imports, as well as for developing more efficient land use and crops. New technologies, such as hydrogenation in presence of catalysts or ethanol-to-diesel routes will help to diversify the feedstock used. Competition with fossil fuel and food supply, combined with volatile prices for the by-product glycerine and changes in the subsidy landscape will represent important additional economic drivers. Further progresses are required due to the range and variability of feedstock for biodiesel production, the need to reduce manufacturing costs and to find new outlets for glycerine as a by-product. It may be also necessary to improve biofuel quality in some cases, such as increasing oxidation stability, or reducing high cold filter plugging points which result from the fatty acid distribution found in tropical oils such as palm oil.

R&D&D Short term (up to year 2013)

Technology improvements required include the need for:

- Acquisition of basic thermodynamic, fluid dynamic and kinetic data for optimisation of existing processes.
- Modelling and experimental verification of the reactions during the biodiesel synthesis in a dynamic multi-phase regime.
- Benchmarking of current biodiesel production technologies in terms of yields, costs, GHG emissions, etc.
- Multi-feedstock biodiesel production technologies with current, available technology to improve overall process economy.
- Improved catalyst recovery and phase separation technology.
- Improved low-cost multi-feedstock oil pre-processing techniques.
- Improved energy efficiency of biodiesel production processes.
- Integration of the up- and down-stream processing steps.

- Glycerine purification and conversion.
- Research on new applications of other by-products than glycerine, like press residue or green parts of the oil plants.
- New processes for generating fuels equivalent to fossil diesel from triglyceride feedstocks.
- Development of technologies to improve oxidation stability, cold flow properties and other product quality requirements for existing and new feedstocks.
- Development of hydrotreating in order to use a wider range of feedstock.
- Use of bioethanol instead of fossil-derived methanol as a reactant to obtain biodiesel (thus yielding fatty acid ethyl esters or FAEE instead of conventional fatty acid methyl esters or FAME), which would make this biofuel fully renewable.
- Co-processing of oils and fats in mineral oil refinery processes (cracking, hydrotreating).

R&D&D Medium term (up to year 2020)

New opportunities and developments for the mid-term include:

- New applications and processes utilising glycerine as well as processes that produce high purity glycerine directly.
- Production technology for new feedstock sources.
- Demonstration units on pre-industrial scale for new multi-feedstock technology.
- Development of high efficient catalysts and related processes.
- Innovative up- and down-stream processes for biomass separation and product purification.
- New fuel additives, providing improved combustion.
- Studies and critical assessment of current biodiesel technology compared with other potentially competing technology like "Hydrotreated biodiesel", fat pyrolysis technology and upcoming BTL technologies.
- Development of lower cost hydrotreating processes.

2.2.3 B. The Biochemical Pathway (Ethanol Production)

Since at present bioethanol is produced from crops that also serve as food or animal feed there is a need to develop alternative pathways that will enable the production of fermentation feedstreams (sugars) from a broader range of cellulosic and lignocellulosic feedstocks derived from residues, waste materials and energy crops. This area will require extensive R&D&D input and process technology development with the need for levels of investment that are significantly higher than at present.

The development of fermentation routes to other biofuels is required in order to create additional flexibility and options in terms of blending ratios and blending components. Technology development has also to be intensified in this area.

If co-products from bioethanol production cannot be marketed cost-effectively, they may be digested anaerobically to yield biogas. This represents a viable option for co-generation of energy that may be utilized internally or externally to the fermentation process.

The scale-up of these processes is a critical step for technology development. Strong support is required to leverage the high risk associated the development of this technology to the market.

R&D&D Short term (up to year 2013)

In the short term there are some areas where current ethanol production systems might be improved. In starch hydrolysis the use of plant borne enzymes, plants modified to produce different forms of raw starch and the identification of new sources of enzymes and improved fermenting organism improvement would be beneficial.

New process developments and implementation of new technology could include pre-fractionation of cereals as well as post-fermentation process to utilise residual starch and non-starch fractions including improvement of the quality of co-products such as enhancing the nutritional value of distillers dried grains (DDGs).

Alternative process flow systems can be introduced for the reduction of energy and operational costs in distillation and more general process optimisation of factory configuration involving energy integration and water management.

A key technology development to be addressed is lignocellulose hydrolysis. More work is required on most aspects of the production chain including pretreatment and biomass fractionation technologies (using physical biological, chemical, thermal and/or thermochemical methods). There is also a need to develop improved enzyme mixtures. This includes the identification of new proteins and development of production strains as well as enzyme processing and manufacturing technologies.

There is also a need for more basic research, increasing understanding of cellulose and plant wall structure as well as the mode of action of cellulases, hemicellulases and cellulosomes. Studies are also required on organisms for the fermentation of mixed feed streams of C5 and C6 sugars as well as ways for valorisation of non-fermentable biomass fractions. This requires both product identification and production process development.

As processes are identified they will have similar requirements for process optimisation in terms of water management, energy integration and plant configuration as for current sugar and starch based systems. Hence, development of factories combining sugar and starch conversion technologies with lignocellulosic conversion technologies (hybrid concepts) should be encouraged in order to enable/boost the transition to lignocellulosic stand alone systems.

R&D&D Medium term (up to year 2020)

Carbon sequestration technologies can be introduced to improve GHG performance. This can be associated with the boilers producing heat and power for the process and/or with the fermenters.

Other oxygenates and liquid biofuels produced by fermentation, such as butanol, raise issues of fermentation and separation processes. Producing components such as acetals, which can be incorporated in a diesel pool is of special interest. Ethanol can be further transformed in order to obtain a fuel compatible with diesel engines. It can be used for producing FAEE, as indicated in paragraph 2.2.3 A. Other possible conversion processes such as oligomerisation have to be further explored also, as well as new chemical routes to convert ethanol precursors (e.g. starch, sugar) into diesel oil components.

There are also requirements for process development and improvements in biogas and landfill gas production including better understanding of the digestion process and digestion organisms.

2.2.3 C. The Thermochemical Pathway

At present, the main R&D&D task is the validation of the overall technical concepts of the thermochemical pathway, the process technologies and the components. There are only a very limited number proof-of-concept (pilot plant, technology demonstrator) scale installations under construction, or in a phase of advanced planning that includes the essential two or three technically unproven steps (gasification, gas cleaning and also product synthesis). These are all at a capacity in the range of 10-45 MW thermal, i.e. at a scale of approximately 10-20% of the expected commercial scale, the latter being foreseen to be in the range of 100-500 MW thermal, and are today typically focusing on lignocellulosic feedstock.

The next step in the R&D&D path is to prove the existing concepts followed by scale-up and development of industrialised, reliable designs and components. This scale-up process is an absolute requirement for achieving a significant contribution through these technologies to biofuel production in the coming decade. In parallel, new and advanced systems have to be developed. The new processes, which are required, have to be more efficient and more flexible in using a variety of feedstock in the same installation.

R&D&D Short- term (up to year 2013)

Research activities in this area, at laboratory scale, were initiated in the 1970s and hence the fundamental aspects are reasonably well established. Generic systems and their components e.g. fluidised beds, entrained flow gasifiers, feed systems etc. have been developed and used to a certain extent already. As indicated above, scale-up from the present stage of development to pilot plant or technology demonstrator and further to industrial demonstration are the main development issue. At present there are only a few concepts and technologies in this area that have already been developed to, or that can reach this stage, within a few years. Hence, scale-up is not at present dependent on

R&D. However, as listed below, there are activities that are supportive to the scale–up path, but not a pre-requisite to the scale-up itself. These include:

- Mechanical, physical and thermochemical pre-treatment for advanced gasification systems.
- Thermochemical processing (gasification, high temperature gas treatment and cleaning).
- Adapt/develop/demonstrate improved fuel feeding systems.
- Advanced gasification technologies for synthetic fuel production (oxygen or indirect gasification).
- Improve knowledge of fuel conversion and gas phase chemistry.
- Improve knowledge of ash and other inorganics and their interactions.
- Development, improvement and optimisation of high temperature gas cleaning.
- Address process design, scale-up procedures and optimisation issues.
- Address process containment cost, and reliability improvement issues.
- Demonstrate performance data by accumulating operational hours.
- Develop and demonstrate fuel flexibility within a given process system.
- Benefit from co-gasification with coal.

Gas upgrading to synthesis gas can be achieved by adapting, demonstrating and optimising existing industrial processes as well as developing novel separation processes based on membranes, Pressure swing adsorption (PSA) etc. These can have associated carbon sequestration technologies to improve GHG balance.

The conversion of synthesis gas to biofuels is established technology. However, it is necessary to develop, adapt and demonstrate the Fischer-Tropsch processes as well as Methanol/DME and mixed alcohol processes in biomass-based systems. Process optimisation will be required in order to improve process performance and reduce the cost of production. Since the thermochemical routes generate large amounts of heat, the possibilities of using this in polygeneration systems should be investigated.

R&D&D Medium term (up to year 2020)

In the mid-term new opportunities and developments should cover alternative process designs. This will include the study and development of alternative gasification systems, such as allothermal gasification and systems in which hydrogen is added from an external source as well as the use of plasmas for gas cleaning. The possibility of generating gaseous fuels (synthetic natural gas and hydrogen) should also be investigated as should processes for other potential biofuels.

Basic R&D should be carried out on development of catalysts for production of ethanol and mixed alcohols from synthesis gas. This should include investigations of biological routes from synthesis gas to such products as part of the development of biorefineries.

2.2.4 The Biorefinery Concept

The R&D&D required in this area is more application- oriented and deals with the integration and optimisation of a number of technologies into a multiple feed, multiple processing and multiple product network. In this report the definition of the term biorefinery developed within the framework of 'IEA Bioenergy Task 42 on Biorefineries' is adopted. This defines a biorefinery as a facility for 'the sustainable processing of biomass into a spectrum of marketable products.'[15]

This definition includes:

- Biorefinery: concepts, facilities, plants, processes, cluster of industries.
- Sustainable: maximising economics, minimising environmental aspects, fossil fuel replacement.
- Processing: upstream processing, transformation, fractionation, thermo-chemical and/or biochemical conversion, extraction, separation, downstream processing.
- Biomass: crops, organic residues, forest residues, aquatic biomass etc.
- Marketable products: both intermediates and final products (i.e. fuels, power/heat, food, feed, chemicals, materials).

Within this complex one or more of the marketable products will be a biofuel for transport. However, different biorefinery concepts can be distinguished. These include factories running conventional (industrial) processes that convert biomass into a spectrum of marketable products (such as paper pulp mills, starch and syrup factories, cane-based sugar factories, etc). Possibilities exist for integration of biomass conversion processes into existing industrial infrastructures in order to upgrade them into a system for sustainable processing of biomass into a spectrum of marketable products. Alternatively, completely new biorefinery concepts can be developed, demonstrated and implemented.

[15] *IEA Bioenergy task 42 on Biorefineries (concept definition), http://www.ieabioenergy.com/Task.aspx?id=42*

Depending on the type of raw materials, various types of biorefineries can be distinguished as follows:

- Oil Biorefinery: feeding biomass and/or biomass-derived intermediates into an existing conventional mineral oil refinery.
- Green Biorefinery: raw materials are "nature wet" biomasses, i.e. green grass, lucerne, clover.
- Whole Crop Biorefinery: raw materials are cereals, maize, etc.
- Lignocellulosic-Feedstock Biorefinery: raw materials are "nature dry" biomasses, i.e. wood, straw, etc.
- Marine Biorefinery: raw materials are microalgae, (seaweeds).

Present status

Currently the biorefinery concept is already applied in a number of industrial sectors. These include the sugar and starch industry, the pulp/paper industry, the soy processing industry, and various aspects of the food industry. As far as the production of conventional biofuels for transport (i.e. bioethanol and biodiesel) is concerned the processes used are focussed mainly on the production of the biofuel with the residues generally used as animal feed. In some cases it is possible that upgrading of the residues into value-added products (materials/chemicals) will decrease the production costs of the biofuels, increasing their market competitiveness.

Progress required

The implementation of biorefinery concepts is needed in the biofuel for transport sector in order to reduce the net biofuel production cost by co-producing value-added products from crop and process residues, increasing overall market competitiveness. This should also improve overall ecological chain efficiency (i.e. minimising greenhouse gas emissions). By using biomass for the production of a portfolio of bio-based products using the biorefinery approach, the raw

materials are converted with the highest possible efficiency decreasing overall biomass use.

R&D&D Short term (up to year 2013)

In the immediate future the following actions are required in order to further the biorefinery concept:

- Market analysis on current and future types, volumes and prices of value-added materials and/or chemicals to be co-produced with biofuels to increase their market competitiveness.
- Identification and lab-scale production of most promising platforms and functionalised bio-based chemicals that can be applied in the existing petrochemical infrastructure.
- Optimisation of current biofuel production processes by full integration of composing processes (a.o. fermentation, digestion and thermochemical conversion processes).
- Valorisation of by-products of conventional biofuels (biodiesel and bioethanol).
- Alternative lignin applications.
- Lab-scale development of innovative biomass pre-treatment processes for the upstream separation of value-added products (primary biorefinery).

- Lab-scale development of advanced (catalytic) biochemical and thermochemical conversion processes (a.o. fermentation, pyrolysis, staged gasification, hydro thermal conversion, etc).
- Lab-scale development and integration of innovative high-efficient and low cost product separation and upgrading processes.
- Lab-scale development bio-based catalytic processes.
- Proof-of-Concept (PoC) of upgraded industrial infrastructures (a.o. Oil Biorefineries).
- Proof-of-Principle (PoP) new biorefinery concepts with focus on: i) large-scale central biorefinery processes using domestic and imported crops, ii) small-scale decentral biorefinery processes using organic residues and/or crops, and iii) combinations of small-scale decentral primary biorefinery with large-scale central secondary biorefineries.
- Development and application of LCA methodology for integrated biorefineries.
- Full chain assessment of integrated biorefinery concepts to identify: i) most promising chains and ii) white spots requiring additional RTD, and to show the advantage of the biorefinery approach over production processes concentrating on the production of a single product.
- Analysis and development of full biomass supply chains, i.e. biomass production till product end-use, incl. logistical aspects.

R&D&D Medium term (up to year 2020)

In the medium term there is a need for:

- Development of new land and marine crops specially applicable for biorefinery purposes (concentration of desired components).
- Identification and lab-scale production of most promising platform and functionalised bio-based chemicals on which a new bio-based chemical sector could be build (sugar chemistry, oleochemistry, amino acid chemistry, etc).
- Development new synthesis pathways to convert platform and functionalised chemicals into marketable end-products.
- Proof-of-Concept (PoC) of new biorefinery concepts (building and running of pilot-plants).
- Proof-of-Feasibility (PoF) and commercial implementation upgraded industrial infrastructures.

R&D&D Long term (up to year 2030 and beyond)

In the longer term actions required include Proof-of-Feasibility (PoF) and implementation of new biorefinery concepts (building and running of demonstration plants) followed by commercial market implementation

2.2.5 R&D&D Roadmap

R&D&D needs on conversion processes identified above are visualised in Figure 2.2 with indication of the main R&D&D activities or areas, their time frame and key development or implementation milestones when appropriate.

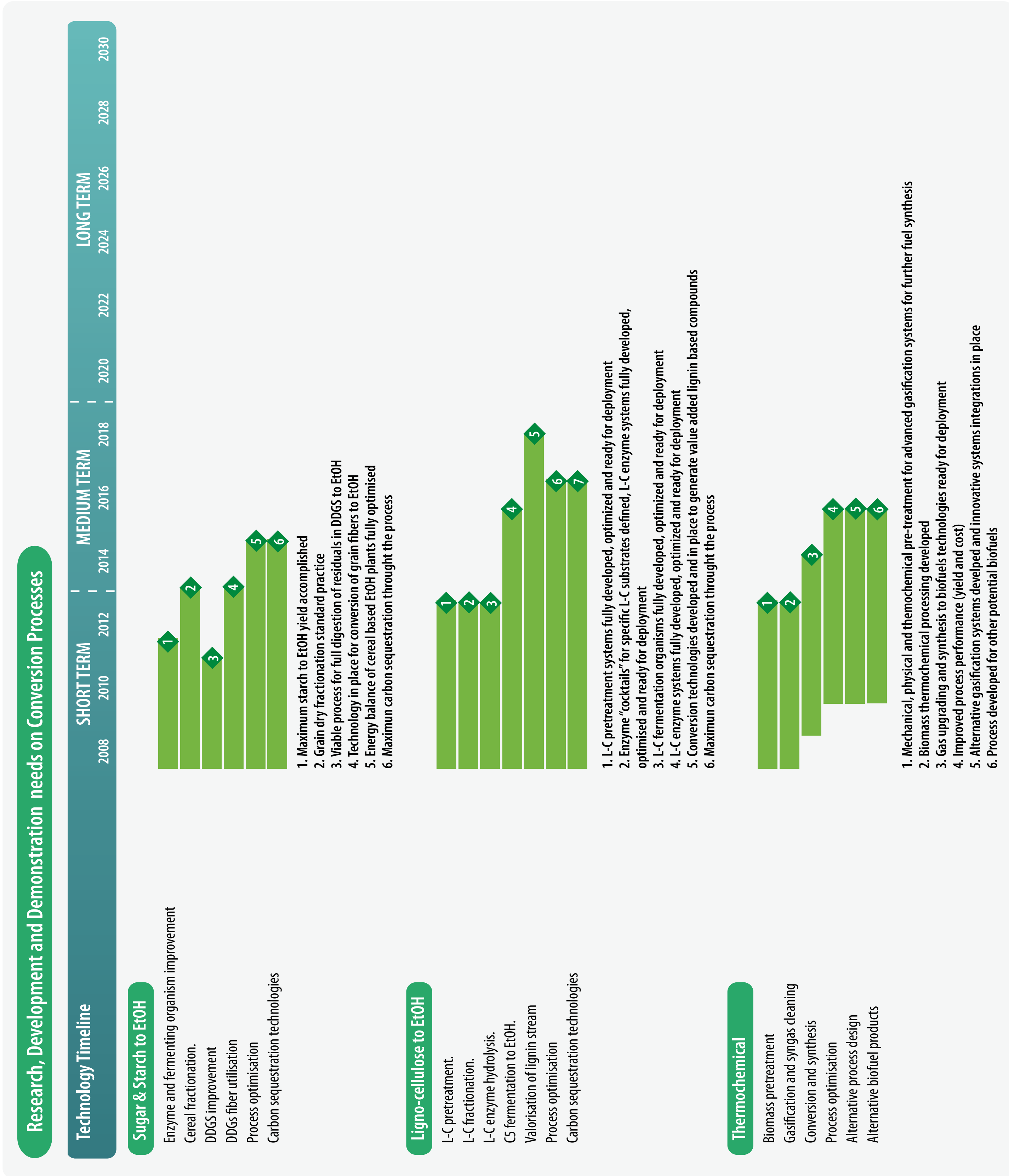


Figure 2.2. *R&D&D needs on conversion processes (continued overleaf)*

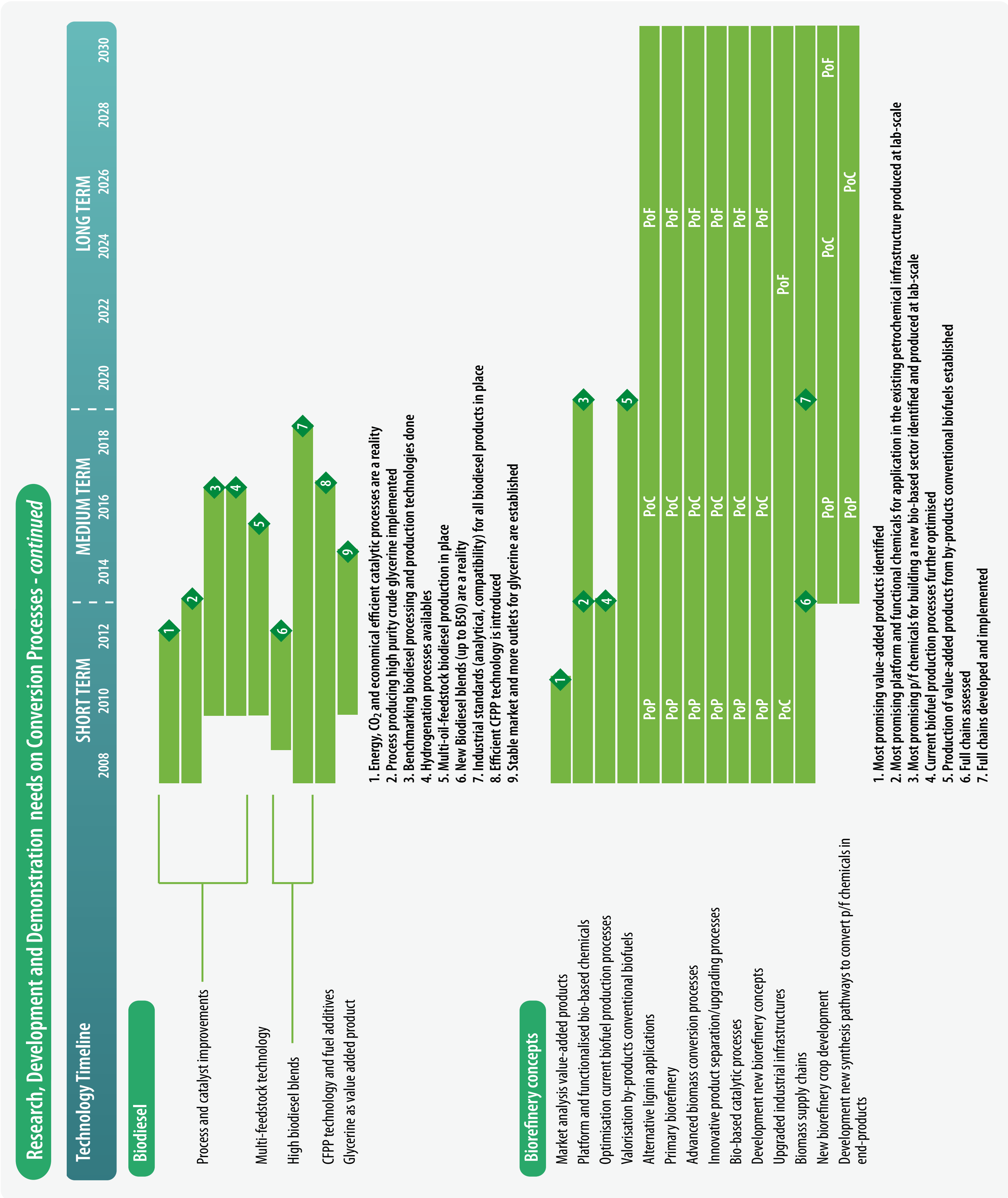


Figure 2.2. *R&D&D needs on conversion processes (continued from previous page)*

2.3. End Use of Biofuels

The increased use of biofuels impinges on two important areas; fuel distribution and end use of biofuels. This section outlines the R&D&D needs covering these aspects of the biofuels chain.

2.3.1 Fuel Distribution

Fuel supply and distribution systems are expected to be more sensitive to current biofuels than to later generation fuels as the quality of future biofuels should improve. The chemistry of current bio-components (biodiesel and bioethanol) leads to possibilities of certain incompatibilities with materials used in fuel distribution systems as well as contamination in manufacturing and transport that need to be addressed.

Future biofuels produced using thermochemical and catalytic systems (such as BTL), or through hydrogenation of vegetable oils are expected to have less impact on distribution system. Research issues may arise concerning the penetration of new fuel types and blends into the market. For instance there can be problems with spark ignition engines using blends of high biofuel content distributed by pipeline and for compression ignition and with gas engines in the supply and distribution of biogas and hydrogen.

2.3.2 End Use in Vehicles

Comprehensive knowledge of the performance of various types of biofuels in existing and future powertrains is essential in order to make an informed choice between promising biofuels, whether used as neat fuel or blended with existing fossil fuels. Logistic issues are also important as engine configurations may have to be adapted to a specific biofuel. This in turn has to be widely available at the many fuelling stations to make conversion worthwhile. To ensure the compatibility of fuel with engine and vehicle the development of standards for neat liquid and gaseous biofuels as well as for fossil fuels blended with biofuels is required.

2.3.2.1 Progress Required

Future increase of biofuel shares in road transportation fuels driven by the European legislation requires intensive progress to be made in biofuel development and introduction. At the same time emission standards will become more stringent in the future (Euro V, Euro VI and further[16]). These require great efforts in the development of compatible vehicle technology. Against this background the development and evaluation of fuels with a high content of biofuels allowing a reliable, customer-accepted operation of vehicles and compliance with upcoming emission standards will be the main challenge in the future. Biofuels and/or biofuel blends both for compression ignition (CI, diesel) engine and spark ignition (SI, gasoline) engines with the following characteristics have to be identified, investigated and made available:

- Safe and reliable vehicle operation of future engine technology even with high blending ratios.
- Compatibility with existing fleet vehicles even in high blending ratios; this is a prerequisite for fast high.
- Volume introduction of biofuels into the market.
- Compliance with future emission standards.
- Overall high CO_2 efficiency (field-to-wheel) and crop yields.
- Easily introduced to existing supply chains.
- Long-term economic/commercial feasibility.

In order to select the most suitable biofuels for application of R&D&D efforts it is essential to understand future fuel requirements. This has to be based on a fundamental understanding of fuel property impacts on engine/vehicle performance. Furthermore a consistent fuel specification and harmonised introduction to the EU market as a whole is required for a fast and efficient deployment of biofuels and to ensure compatibility with the complete vehicle fleet. In addition it may be necessary to develop advanced vehicle and engine technologies for dedicated biofuels/blends (e.g. E85, BTL) or for specific applications or demands of the market.

2.3.2.2 Vehicle and Engine Issues Impacted by Fuel

Properties

A number of vehicle issues are affected by the properties and quality of fuel used. These issues require special attention and should be particularly addressed in future R&D&D activities when studying fuel impacts on engine and vehicle operation. For the fuel supply system these include long-term fuel storage stability (avoiding ageing effects, deposits, biological growth), material compatibility with fuel tanks, seals, gaskets, hoses, pipes, fuel filters and fuel pumps.

[16] *Regulation (EC) No 715/2007, June 2007.*

Considerations of engine performance and fuel combustion have to cover engine power, fuel efficiency, CO_2 emission (Tank-to-Wheel), local emissions (NOx, HC, CO, PM), cold startability, hot driving performance and engine noise. At the same time fuel developments have to take into account compatibility with existing engine technology (the current fleet of vehicles), as well as the potential for improved engine technology, including aspects such as late homogenisation, which is important in diesel engines when developing new/modified combustion schemes.

Aspects of engine mechanics that need to be considered include injector and combustion chamber cleanliness, friction and associated with this engine oil compatibility, which in turn contributes to overall reliability and durability. The after-treatment of exhaust gas in order to control emissions is of equal importance, depending on the performance and long-term durability/stability of EGA (Exhaust gas aftertreatment) components including oxidation catalyst (CI engine) the performance and regeneration of diesel particulate filters (CI engine), the use of three-way catalyst including advanced forms (SI engine), the use of NOx storage catalyst and the performance of lambda and NOx sensors.

As far as vehicles are concerned the fuels used must enable an acceptable driving range and meet health and safety requirements in terms of toxicity of substances, flash point, fuel vapour pressure, etc.

2.3.2.3 R&D&D Needs and Timeframe

The R&D&D requirements reflect the properties of fuels required for two completely different ignition systems (compression or spark ignition). Hence, these are considered separately.

Fuel Property		Diesel Fuel Current Standard [EN590]	Expected Change due to Future Evolution of Conventional Engine Technology	Expected Change Required for Future Combustion Schemes
Ignition Behaviour (Cetanre nr)	-	min 51	not defined	not defined
Sulfur Content	mg/kg	max 10	lower	lower
Ash Content	% (m/m)	max 0.01	lower	lower
Water Content	mg/kg	max 200	lower	lower
Water Solubility		not specified	to be defined	to be defined
Oxidation Stability	g/m³	max 25	to be defined	to be defined
Lubricity (HFRR)	µm	max 460	lower	to be defined
Viscocity (at 40°C)	mm²/s	2.0-4.5	to be defined	to be defined
Distillation Behaviour Distillation Curve			to be defined	to be defined
+95% Recovered T		max 360	lower	lower
Final Boiling Point	°C	not specified	to be defined	to be defined
Metals Content (Na, K, Mg, Ca)	mg/kg	not specified	to be defined	to be defined
Phosphorous Content	mg/kg	not specified	to be defined	to be defined
Heating Value	MJ/kg	not specified (=ca 43)	to be defined	to be defined

Table 2.1. *Important fuel parameters for future CI engine technology and their expected change needed for complying with future fuel requirements*

a) Compression ignition (CI) engines

The impact of fuel properties of CI engine fuels on vehicle issues as described above is still not completely known or understood. Therefore, fundamental research is essential in order to expand basic knowledge in this area. Such information would provide a basis for defining the properties of future fuels. In this respect the following fuel properties are regarded as of particular important for future CI engine technologies: ignition behaviour; distillation characteristics; absence of fuel impurities (sulphur, metals, phosphorous); ash content (low); hygroscopic potential (water controlling contamination through biological growth, phase separation), lubricity, viscosity, oxidation stability, cold startability, biological growth (lack of).

The qualitative change in fuel specifications required for complying with future conventional and new combustion scheme technologies of CI engines are shown in table 2.1. It is anticipated that future requirements in terms of fuel quality will increase, while a number of fuel properties regarded to be important for future vehicle and engine technology are not specified in the current fuel standard EN590. Hence, for a large number of fuel properties future requirements still have to be worked out and defined considering issues both, for passenger cars and commercial vehicles.

The suitability of biofuels with respect to future fuel requirements has to be evaluated. Investigations have to be carried out on currently known potential biofuels, such as biodiesel, Hydrotreated Vegetable Oil (HVO) and BTL. Compliance of these biofuels with future requirements has to be evaluated. These studies have to cover both the use as neat fuel or as blends with fossil diesel. In addition, extensive R&D activities also have to focus on the development of new types of biofuels with improved fuel properties, CO_2 balances and higher yields.

R&D&D Short term (up to year 2013)

Fundamental research is required in order to increase understanding of the impact of fuel properties on engine/vehicle performance of future CI engines as well as on both conventional and new combustion schemes. There is also a need for verification of the performance of known and proposed biofuels (biodiesel, HVO, BTL) when used as a pure fuel or used in blends with fossil diesel in existing and future CI engines.

R&D&D Medium term (up to year 2020)

Fundamental research providing an understanding of the impact of fuel properties on engine/vehicle performance of future CI engines will have to be continued as new commercial sources of biofuels develop and the fuel requirements for existing and future CI engine technology/engine and vehicle testing are elaborated. This includes verification of known potential biofuels (Biodiesel, HVO, BTL), neat and blended to fossil diesel, for application with existing and future CI engine technology as well as verification of novel-type biofuels (neat and blends) with better fuel properties, CO_2 efficiency, higher yields for applicability in existing and future CI technology (e.g. new biomass sources, use of ethyl esters of fatty acids rather than methyl esters). It will also be necessary to identify and formulate potential biofuels/blends in order to meet the 10% target. Development of such commercial fuels (neat or blends) will also require consideration of suitable fuel additives.

R&D&D Long term (up to year 2030 and beyond)

Work on potential biofuels (neat or blended to fossil diesel) for applicability in existing and future CI engine technology will have to continue as new products are identified. This will include elaboration of fuel requirements for existing and future CI engine technology/engine and vehicle testing as potential biofuels/blends are identified in order to meet the 25% target of the BIOFRAC Vision. Again this will entail development of commercial fuels, neat or blends, and further consideration of fuel additives.

b) Spark ignition (SI) engines

As is the case for CI engines there is also a need to obtain further information concerning the interrelation between the properties of fuels used with SI engines and vehicle issues. Fundamental research is essential in order to expand basic knowledge in this area in order to provide a basis for the definition of future fuel requirements. The following fuel properties are important in respect of future SI engine technology development: ignition behaviour; distillation characteristics; vapour pressure characteristic; alcohol type/content; hydrocarbon type content (olefins, aromatics); fuel impurities (e.g. sulphur); hygroscopic potential (water content/solubility) and lubricity.

Fuel Property		Gasoline Fuel Current Standard [EN228]	Expected Change due to Future Evolution of Conventional Engine Technology	Expected Change Required for Future Combustion Schemes
Ignition Behaviour (e.g. RON, MON)		RON/MON 95/98 (premium grade)	to be defined	to be defined
Hydrocarbon Type Content + Olefins	%(V/V)	max 18	lower	to be defined
+ Aromatics		max 35	lower	to be defined
Vapour Pressure min/max	kPa	Class A 45/60	lower	to be defined
Oxygenates Content Methanol, Ethanol, i-Propanol, i-Butanol, t-Butanol	%(V/V)	max 3 / 5 / 10 10 / 7	to be defined	to be defined
Distillation Behaviour		not specified	to be defined	to be defined
Water Content/Solubility	mg/kg	not specified	to be defined	to be defined
Lubricity		not specified	to be defined	to be defined
Fuel Impurities	mg/kg	not specified	to be defined	to be defined
Heating Value / Energy Density	MJ/kg	not specified	to be defined	to be defined

Table 2.2. *Important fuel parameters for future SI engine technology and the expected changes required*

Table 2.2 indicates the qualitative change of fuel specifications required in order to comply with the requirements of future conventional and new SI engines with advanced combustion scheme technologies. Future requirements with respect to fuel quality will increase, while a number of fuel properties regarded to be important for future vehicle and engine technology are not specified in the current fuel standard EN228. Hence, for a large number of fuel properties, future requirements still have to be worked out and defined. Investigations have to be carried out on current biofuels (ethanol) and compatibility of these biofuels with future requirements has to be verified. Studies should consider the biofuels as neat fuel or blended with fossil gasoline. Furthermore, focus should be on the development of new types of biofuels with improved fuel properties, CO_2 balances and higher yields.

R&D&D Short term (up to year 2013)

There is a need for fundamental research in order to understand the impact of fuel properties on engine/vehicle performance of future SI engines including both conventional and new combustion schemes, as well as verification of the performance of known biofuels (ethanol), neat and blends with fossil gasoline, for application in existing and future SI engines.

R&D&D Medium term (up to year 2020)

Fundamental research leading to an understanding of the impact of fuel properties on engine/vehicle performance of future SI engines should continue, with elaboration of fuel requirements for existing and future SI engine technology including both engine and vehicle testing. This should include verification of the performance of ethanol (neat and blended to fossil gasoline) with both existing and future SI engine technology. Similar studies are required for new or novel biofuels (neat and blends), as they are developed, for application in existing and future SI engines together with the identification of potential biofuels/blends in order to meet the 10% target of the SET-Plan. This should lead to development of commercial fuels (neat or blended) that will also require consideration of fuel additives.

R&D&D Long term (up to year 2030 and beyond)

As new routes are identified producing new classes of biofuels this will again require verification of their performance (neat or blended to fossil gasoline) applicability in existing and future SI engines. At the same time it will be necessary to continue the elaboration of fuel requirements for these engines, including engine and vehicle testing as potential biofuels/blends are identified that will allow the 25% target of the BIOFRAC Vision to be met, resulting in the development of commercial fuels, used neat or in blends. This will again require development of suitable fuel additives compatible with the new biofuels.

c) Gas engines and vehicles

Biogas, which is processed for usage in vehicles, is expected to have similar or even higher quality, once purified, compared to CNG available on the market today. Therefore, no additional research effort regarding vehicle technology is required beyond current research activities on natural gas engines. However, further effort is required to optimise production and purification of biogas.

2.3.3 R&D&D Roadmap

R&D&D needs on end use of biofuels identified above are visualised in Figure 2.3 with indication of the main R&D&D activities or areas, their time frame and key development or implementation milestones when appropriate.

2.4. Sustainability Issues.

Although there may be aspects of sustainability that apply to specific parts of the biofuel production chain, in general sustainability should be considered in terms of the complete chain, and even beyond such as considerations of land use and competition for resources like biomass and labour.

However, analysis of alternative systems is complex since, even if a segment within the overall chain is not sustainable, the overall supply chain might be more sustainable compared to a given alternative. In addition, the linkage between different segments has to be done in a sustainable way.

Organisations in several EU Member States have already been working on the development of full-chain sets of criteria for biofuels sustainability. These include the Low Carbon Vehicle Partnership in the UK, the Cramer Commission in the Netherlands and initiatives in Belgium and Germany. Most sustainability schemes try to include criteria covering three aspects: environment, social and economic aspects.

Advances in current initiatives provide a fair indication of the progress required that fall into three main fields. These are: a) further development of indicators and methods (this applies to criteria in environmental, social and economic domains); b) assessment and monitoring (e.g. collection of data and corresponding monitoring schemes), and c) improvement of sustainability aspects.

An important second aspect of sustainability relates to competition of energy crops with other biomass production and use, indirectly leading to issues concerning sustainability. For example, a biofuel feedstock plantation that replaces common food crop cultivation may cause natural areas to start being used for food crop cultivation, thereby indirectly leading to deforestation. Another example is that increasing demand in feedstock for biofuels could lead to increasing commodity prices to socially unacceptable levels, which cannot be tackled at company level or by production chain certification.

Strategies to overcome these issues are on one hand improvement of measurement methods and impact monitoring, and on the other hand methods and approaches to reduce competition for land.

2.4.1 Research Needs

R&D&D Short term (up to year 2013)

There is a need for further identification and development of sustainability indicators tackling the overall chain based on existing work adapted to very different situations (e.g. type of feedstock, geographical area of production, technology, end use, local constraints). This requires continual improvement and development of flexible and transparent WTW methodologies including technical, economic, environmental, and social aspects such as LCA and Socio-Eco-Efficiency-balance.

There is a need for further improvement of data obtained throughout the overall biofuel chain (e.g. on soil C, N_2O, new crops, and commercial scale plants) for most biofuels, both current and proposed, as well as for fossil reference

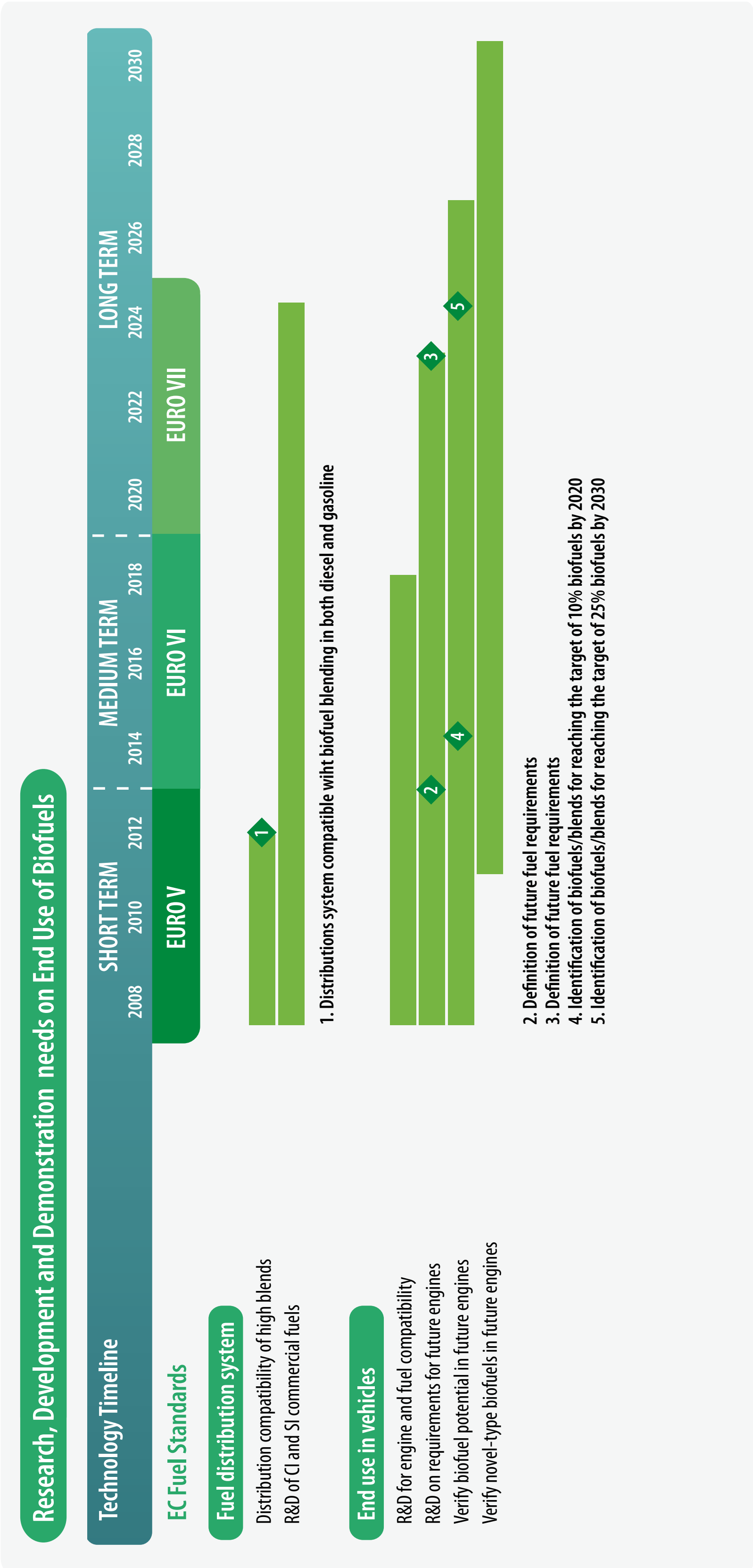


Figure 2.3. *R&D&D needs on end use of biofuels*

chains for comparative purposes. This requires further development of indicators and methods tackling social and environmental issues that could be achieved through establishing additional working groups throughout Europe (especially in Eastern Europe).

As for the systems impacts, there is a short-term need for better measurement and monitoring of these effects, e.g. in the form of parameter selection and (satellite) gathering of relevant data. Furthermore, it is essential to improve insights in the sizes of impacts, e.g. of deforestation and commodity price increases due to biofuels, since many of the effects we currently see may also be caused by other factors.

R&D&D Medium term (up to year 2020)

Assessment of existing and future biofuel supply chains should be based on existing, improved and new methods or indicators linked to monitoring of the development of biofuel markets. At the same time data should be gathered on key indicators in order to evaluate and monitor various biofuel chains under very different scenarios of feedstocks used, production technologies and end uses.

As for systems impacts and sustainability, there is a need for development and deployment of innovative options, increasing land use and production efficiency, such as those based on: agroforestry (creating synergies between food, fodder, raw material and energy production), multiple land use (delivering other land-related services such as environmental protection together with energy feedstock), and flexible production systems switching between supply of food, fodder, raw material and energy crops. Furthermore, research is needed on improving the use of marginal and/or degraded land, on concepts to use the existing (native) forests in a sustainable way by maximizing the wood yields and minimizing the environmental impact, and on unused or innovative resources (like the production of aquatic biomass).

R&D&D Long term (up to year 2030 and beyond)

Further work should result in improved chain integration based on accepted sustainability criteria. This should lead to identification of various aspects affecting the sustainable performance of specific production chains resulting in development of solutions indicating how the situation could be improved. This will require an overall methodological approach to be compiled.

2.4.2 R&D&D Roadmap

R&D&D needs on sustainability identified above are visualised in Figure 2.4 with indication of the main R&D&D activities or areas, their time frame and key development or implementation milestones when appropriate.

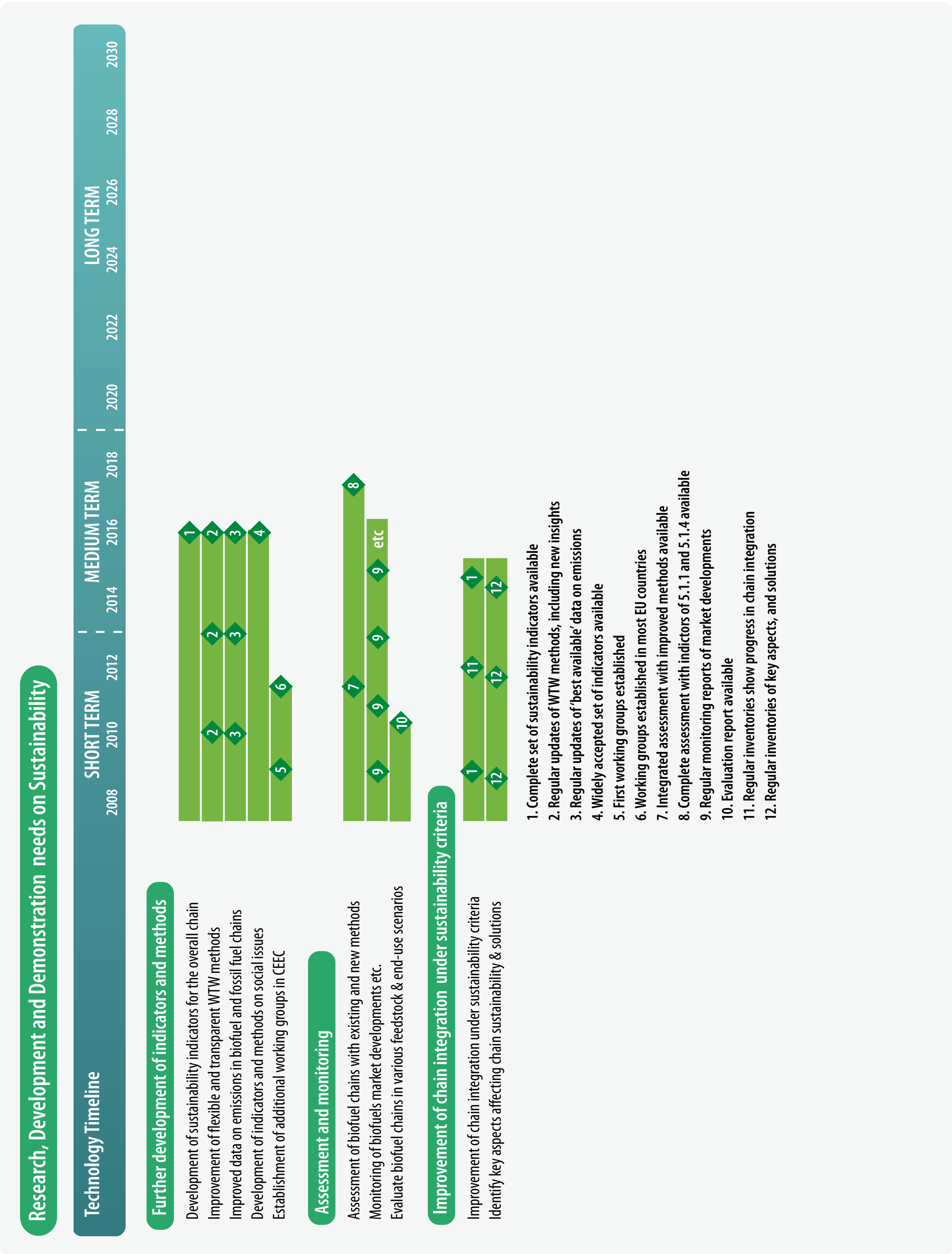


Figure 2.4. *R&D&D needs on sustainability*

3. BUILDING R&D EXPERTISE

There are innumerable organisations worldwide (corporate, institutional & academic) that are researching solutions to the challenges posed in converting biomass to liquid transport fuels in an economic and sustainable way. Such organisations may operate individually or in partnerships and collaborations, being self-funded or receiving external support. The objectives of the research vary from pure research, through intellectual property (IP) generation and licensing to eventual construction of fully fledged commercial biorefineries.

This is, of course, the essence of new market creation through the process of competitive technology development and corporate commitment. At the same time it creates one of the most significant challenges in terms of technical and commercial progress in the area of new technology development – that is the ability to control and manage fragmentation. It is essential that future funding programmes for biofuels are operated in an objective manner such that the most appropriate technology programmes are accelerated and the most relevant deliverables are produced. The need for better communication does not encompass all players, since there will always be competition between companies and hence some will be reluctant to cooperate closely.

Connecting R&D Organisations Through Networking

It is of great potential benefit to promote extensive networking between R&D organisations of all types (corporate, academic & institutional). In so-doing ways must be found to minimise the sensitivity associated with intellectual property. Some potential network platforms could be:

- Best practices networking.
- Networks focussed on common goals.
- Core competence networks.
- Creation of centres of excellence.
- Virtual (cyber) networks that facilitate on-line information dissemination.

Operating Joint R&D Facilities

Both existing and new R&D facilities could be developed and enhanced to support specific biofuels initiatives. This could provide a much needed platform for all industry stakeholders to develop and test new concepts and technologies. For example:

- Pilot scale facilities operated on a fee basis, such as the NCERC at the University of Southern Illinois, USA[17].
- Dedicated biofuel process application laboratories.
- University consortia such as the NTC focussed on the US textile industry[18].

Promoting Cooperation Initiatives at the European and International Levels

Creative ways must be found to promote cooperation at all levels both within and beyond the EU. Fiscal incentives via funding are a common and effective means by which to bring collaborative groups together. However the focus needs to be on the goals rather than the actual funding. Some potential funding mechanisms:

- Pay for performance funding – based on milestones and deliverables.
- Weighted funding that favours collaboration between partners that offer greater up-front contribution – technology, IP, capabilities, co-funding, etc.

Cooperation on a global basis will bring a range of benefits to any given programme – for example:

- Organisations within the EU can learn from and share insight with other regions.
- Ensure that the EU does not "re-invent the wheel".
- Collaboration can specifically engage global based organisations focussed on biofuel technologies.

[17] *http://www.ethanolresearch.com*
[18] *http://www.ntcresearch.org*

STRATEGY DEPLOYMENT DOCUMENT

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4. Public Awareness and Social Acceptance SDD-7

1. INTRODUCTION

The purpose of this Strategy Deployment Document (SDD) is to address the non-technical issues that will enable the European biofuels industry to meet the goals outlined in the BIOFRAC vision report[19]. This document should be read in association with the Strategic Research Agenda (SRA) that has also been produced by the European Biofuels Technology Platform (BiofuelsTP). The SRA identifies research, development and demonstration priorities along the whole value chain of biofuel production (from biomass to biofuel end use) with emphasis on sustainable methods of production.

The Objective

The main objective of the SDD is to identify the non-technical measures including regulations, market instruments, funding and incentives, and communication actions that are necessary in order to generate a sustainable and successful EU biofuels industry that meets the goal of substituting up to 25% of the fossil fuel used for transport with biofuels by 2030 in a sustainable way. These measures are to be developed on the basis of coordinated and strategy-oriented policies.

The Starting Point

At present fragmentation of the market between various Member States of the EU appears to be one of the major reasons for the slow deployment of biofuels. Currently the promotion of biofuels and consequently the measures put in place to help biofuels to find a place on the market are totally dependent on the will and capacity of individual Member States. The result has been a fragmented market with difficult trans-border movement and significant market distortion at EU level.

The current market situation reflects the impact of the Directive 2003/30/EC that was initiated in order to promote biofuels on the basis that their deployment would improve the energy security of the EU, reduce greenhouse gas (GHG) emissions and produce new outlets for agricultural and silvicultural products thus improving rural development.

As the objectives above were not sufficiently prioritised and also because Directive targets were set as "indicative" and not binding, each member state has been able to set their own regulations depending on their perception of national priorities. These widely differ from country to country.

At the same time, current EU regulations are not totally consistent in terms of biofuels use. There are conflicts between market penetration set by the Biofuels Directive (5.75% energy equivalent in 2010) and existing regulation[20] in CEN technical standards[21] that today permit maximum 5% blends of biodiesel (FAME) or ethanol. Higher blends of 85% ethanol (E 85) or 30% biodiesel (B30) have been adopted by some Member States. However, these are not covered by EU Directives or other regulations. This discrepancy has been noted and proposals made to rectify it.[22]

During the assessment exercises carried out by the various workgroups of the BiofuelsTP[23] it was recognised that important factors that would determine the possibility of reaching the 'vision' goals included change and harmonisation of regulations that would improve biofuels market access. It should be noted however that, although in the short-to-mid term a significant level of regulation and support measures may be required, biofuels will only be competitive in the long term if they can become cost effective and thus competitive to fossil fuels in a free market. This requires an analysis of actions that may be deployed in order to improve the economics of biofuel production in the mid-term.

The SRA indicates that this will depend on the development of advanced biofuel technologies able to use a wide range of feedstocks. The development of such new technologies will require significant investment that must come from both public and private sector working in partnership. Such a partnership will only flourish in an open and uniform market supported by suitable regulations, standards and certification that ensures sustainability while providing the customer with a product that is 'tailor-made'.

[19] *Published 2006, Directorate-General for Research, Sustainable Energy Systems, Ref: EUR 22066. (Biofrac. 2006. Biofuels in the European Union. A vision for 2030 and beyond.)*

[20] *Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Council Directive 93/12/EC.*

[21] *Diesel standard: EN 590; Gasoline standard: EN 228; Fuel Qualitity Directive: 98/70/EC, amended by Directive 2003/17/EC; CEN Workshop Agreement on E85 (CWA 15293)*

[22] *The European Commission proposed new standards for transport fuels that will reduce their contribution to climate change and air pollution, through greater use of biofuels, 31 January 2007.*

[23] *See the Strategic Research Agenda for more details.*

2. CONCEPTUAL STRATEGY DEPLOYMENT ROADMAP

Prior to detailing deployment measures it is important to set a conceptual timeframe consistent with strategic targets and expected evolution of technology, as the effectiveness of measures such as market instruments, quality standards, binding rules, financial support, etc are strongly dependent on when they are set and how long they last.

Phase 1, Short term (up to year 2013)

First, there is a need to reconfirm and prioritise as much as possible the declared objectives to promote the use of biofuels, namely reduction of GHG emissions, energy diversification in transport (thus reducing dependency on oil products) and, when appropriate, contribution to development of rural economies.

There is a need to consolidate the market and to reduce the current level of fragmentation in policies among Member States. For key objectives, regulations should be binding rather than non-binding. A regulation or law concerning biofuels accepted by one member state should also be accepted by all the others.

It is necessary to open the biofuels market throughout the EU. Not all Member States are in the position to fulfil the proposed biofuel targets through their own domestic production. Therefore a scheme should be introduced to facilitate the trade of biofuels among Member States, including flexibility instruments (e.g. biofuel credits). As availability of feedstocks will become a challenge, import and export of biofuels to and from the EU should be made easier in order to balance excess or lack of production capacity within the EU.

At the same time sustainability criteria have to be introduced and harmonised under a single European Standard in order to ensure that all biofuels used in the EU are produced in a sustainable way on a "life cycle" basis while maintaining conditions that favour the development of a healthy EU biofuel industry.

General support to agricultural product outlets, today included in biofuel policies, should be at this term included in the scope of the Common Agricultural Policy reform, scheduled to be in place at the end of the period.

There is also a need to harmonise fuel quality regulations and standards to enable biofuels to be produced and marketed in a cost-effective manner, as economics of production is a crucial driver in biofuel development. In general road transport fuels (including biofuels) are designed to fit existing engine requirements. However, higher blends (E 85, B 30 …) might be encouraged in order to meet future targets for fossil fuel substitution, even though the use of such blends requires some adaptation of vehicles.

On the other hand, Research, Development and Demonstration (R&D&D) covering both current and next generation biofuels, as detailed in the SRA, should be financially supported. Specific financial support should be given to demonstration of improved and first-of-a-kind technologies.

In order to gain social acceptance, dissemination and communication of demonstrated biofuels benefits should be pursued in the short term, including those related to education at school, technical and political fora and institutions, media, etc.

Phase 2, Medium term (up to year 2020)

Phase 2 can be envisaged as a prolongation of Phase 1, leveraging on success achieved and correcting any distortions that might have been caused by rules and regulations. With a view to transitioning to a free market, unnecessary new measures should be avoided and existing ones kept simple and harmonious. In general actions taken should open both domestic and foreign markets. Biofuel policy should not be targeted specifically to support agriculture, as support measures to agriculture should be separately managed.

R&D&D on new biofuels should continue receiving financial support. As time passes, technologies will be proven and consolidated through demonstration at which time advanced biofuels will have to compete with all biofuels on the market.

Phase 3, Long term (up to year2030 and beyond)

If the biofuels market develops as anticipated to 2020, incentives should be gradually phased out in third phase. The underlying premise is that biofuels and possibly associated bioproducts produced in biorefineries should be self-supporting by this time.

At this stage, biofuels should be competing with other motor fuels, and those biofuels that have best demonstrated competitiveness and sustainability will succeed in the market place. Market instruments will be in force as required aimed at incorporating sustainability criteria and environmental externalities (e.g. GHG reduction) for energy use , rather than being specific to biofuels.

3. DEPLOYMENT MEASURES

Once a conceptual strategy deployment roadmap has been outlined, details will be presented on the attributes that relevant deployment measures should have in order to ensure that sustainable biofuel technologies are successfully implemented for the benefit of a healthy EU biofuels industry.

A special emphasis will be given first in this report to those measures that support R&D&D consistent with the Mission of the BiofuelsTP.

3.1 R&D&D Support

Very ambitious biofuel implementation targets will require reinforced public and private support to both mid and long term oriented Research, Technology Development and Demonstration (R&D&D) along the whole value chain from biomass production to end use in engines. Current biofuels still show significant room for improvement, while new technologies, such as those necessary for producing biofuels from lignocellulosic biomass need to be developed.

The sustained financial effort required to implement R&D&D priorities as previously identified in the SRA will be high, being roughly in the range of 300-600 million € per year. This includes demonstration up to prototype or semi-industrial size, but still excludes full-size "first-of-a-kind" industrial facilities.

Risk associated with 'difficult-to-assess' economic return of mid and long term R&D frequently make industry behave conservatively in terms of funding R&D sufficiently. Therefore, if biofuel implementation is to be aggressively pursued reinforced public funding will be needed. Public support to R&D&D should be aligned with key strategic goals for biofuel development: GHG reduction, diversification of energy supply, environmental and socio-economic sustainability.

The main problem facing the deployment of innovative biofuel technologies is the difficulty of scaling-up and the lack of pilot initiatives and **demonstration on a large scale**. Beyond "Proof-of-Principle" (PoP) at small scale, technology implementation requires scaling-up by both "Proof-of-Concept" (PoC, showing at pilot scale that the concept is technically working) and "Proof-of-Feasibility" (PoF, showing at demonstration scale that the whole process is technically and economically feasible). Such a scale-up and demonstration chain is essential not only for thermochemical and biochemical processes, but also for integrated biorefinery concepts and end use applications.

Therefore, a high priority for R&D&D in this sector has to be scale-up and development of industrialised, reliable designs and components. This has to be done within the next decade with the technology developed to a stage where multiple plants can be constructed in order to significantly contribute to biofuel production by 2020.

The challenge is to establish technical conditions and meet performance levels that allow scale-up of the required technologies. Demonstration and PoC during the next ten years will be followed by a progressive deployment and improvement of the technology. Without such a step, it will not be possible to meet the levels of biofuel production needed in 2030.

Beyond the technical barriers, it is also necessary to address issues associated with a pioneering technology, such as:

- Financing the development.
- Ensuring long-term guarantees for revenues.
- Creating standards.
- Defining acceptable practices and creating an appropriate regulatory environment.
- Achieving public acceptance through a better awareness of the benefits.

Validating Technologies and Building up Pilot-Scale Infrastructure

The development of innovative processes involves an access to large pilot facilities. It is necessary to facilitate the access to demonstration plants and pilot-scale facilities for R&D work.

This means that such installations should be open to external teams for measurements, side-stream experiments and other basic research activities. This could also benefit the industrial developers by providing access to external R&D expertise.

It is important to establish an infrastructure linking academic research to large scale facility operations in order to improve available knowledge. Such an approach will accelerate the rate of R&D results, while providing leverage for the non-commercial R&D sector. It will help to provide knowledge and manpower requirements needed by an emerging biofuel industry.

The establishment of dissemination networks is also of benefit through the spread of know-how as well as information concerning the performance of equipment, materials and processes to the participating stakeholders, as far as permitted in terms of intellectual property rights (IPR) and commercial confidentiality. To avoid IPR issues, such networks are best used in the development of less commercially sensitive information such as life-cycle analysis, performance data and assessment of "best available technology".

Financing Large-Scale Demonstration Projects

The development of new biofuel production systems will require a very large financial input, particularly for the required conversion capacity to reach 2020 and 2030 biofuels goals. Additional investments for biomass planting, harvesting, transportation and soil conditioning systems as well as additional infrastructure and engine development are going to require further investments. As a reference, an investment cost in the range of 400-600 million € for a 105-120 thousand tons per year BtL plant (next generation lignocellulosic biomass conversion) was reported in a 2006 study[24] coordinated by the German Energy Agency.

For the entrepreneur, while taking into account the considerable technical and commercial risks, costs are one of the main barriers preventing an accelerated development. Financing needs have to be addressed by all stakeholders as a prerequisite to any technical development.

Development of new markets is associated with high risk. Organisations that are prepared to accept greater risks in investing should be equally rewarded by opportunities to participate in initial funding. It is essential that industry is ultimately capable of sustaining itself in a profitable manner but it is necessary to find appropriate mechanisms for helping it to support risk associated with large scale installations in the initial stages of development.

One possible instrument could be a special fund created to assist in financing the costs of the higher risk first-of-a-kind industrial projects. Such a fund would provide a low interest rate loan as well as a guarantee covering at least part of the financial risk. During a first deployment phase, a fiscal incentive would be simultaneously provided in order to compensate the difference between the actual production cost and a reference production cost. This fiscal incentive has to be provided for a sufficient transitional period to ensure that technology can compete on level terms in the market place. At present the size of the fund and level of fiscal support has still to be evaluated. Such evaluation will be carried out in 2008.

Any technology of value should ultimately reach a stage at which it represents an opportunity for globalisation. Hence, it is important that global networks are maintained in order to share regional EU success and learn from developments elsewhere on a world-wide basis.

3.2 Market Instruments and Regulations

As already indicated there is a need to implement coherent and harmonised policy framework throughout Europe. Harmonisation should apply for the whole set of standards, regulations and norms extending to aspects like obligation of use, sustainability certification, trading, product quality specifications, etc. Measures should be aligned with declared strategic goals for biofuels (GHG reduction, diversification of energy supply for transport).

It is important to create an EU-wide level playing field for bio-based products such that specific applications of biomass-derived products are not artificially discriminated against others. There is today a considerable heterogeneity both by biomass application (biofuel, bioheat, biochemicals, etc) and by country that could create market distortions.

There is also a need for evaluation of the coherence and the impacts of any introduced biofuels policy measures with other key EU policy measures relating to aspects such as the environment (including climate change), agriculture, forestry, local development, consumer protection, commercial development and RTD investment.

[24] *Biomass to Liquid – BtL Implementation Report, Deutsche Energie-Agentur GmbH, (The German Energy Agency), Berlin, December 2006*

Product Quality Standards

Both harmonisation at EU level and sound science to establish quality requirements are required, while preventing that quality standards become unnecessary technical barriers for biofuels deployment. The proliferation of different national rules and relaxation of quality levels, conflicting with powertrain requirements, produces market fragmentation and distortion while undermining credibility of motor fuel and biofuel industries.

There is a long history in the EU of developing product quality standards in CEN (European Committee for Standardisation). CEN joins regulators and industry experts to develop quality specifications when required, making use of best available technical knowledge. Specifications covering fuels and vehicles should be preserved. However, it is noted that strict procedures based on experimental evidence adopted by CEN can prolong the introduction of new standards. Development of new standards, associated with production and use of new types of biofuels should be made compatible in terms of timing with the ambitious targets for implementation of biofuels. This will require a continuous and intensive effort during the coming years as new biofuels and engine technologies are developed.

Obligation of Use and Related Mechanisms

Binding rules on biofuel use is a straightforward mechanism for biofuel deployment. As indicated above, quantitative targets should be harmonised across the EU as a first step towards minimizing market distortions.

Complementary measures and norms are then required taking into consideration market dynamics in response to obligation:

- Norms should be made simple and oriented to strategic targets (e.g. GHG reduction) avoiding unnecessary prescription or over-regulation, thus keeping the system as flexible as possible.
- Procedures used to measure the volume of biofuel produced should not prevent the effective deployment of all types. For instance, it should take into account biofuels obtained from refineries where the biomass has been co-processed with mineral oil, for which the contribution is more difficult to measure.
- International trading has to be balanced to make use of foreign socio-economically sustainable biofuels while maintaining conditions for the development of a healthy EU biofuel industry.
- Consideration should be given to the effect of non-compliance penalties (e.g. €/ton not marketed) on biofuel prices.

Sustainability and Certification

As biofuels gain market share and international trading of biomass, raw materials and biofuels expands, the need to ensure socio-economic sustainability along the whole supply chain becomes more pressing. This includes aspects such as land use, agricultural practices, competition with food, energy efficiency and GHG emissions, life cycle analysis (LCA), etc.

Sustainability of a given biofuel needs to be guaranteed in a transparent way; this is only possible if appropriate policy measures influencing and steering the overall supply chain are adopted. Penetration of biofuels within the transport sector has so far been dependent on policy measures (such as a quota and tax exemption). Such measures should allow for a sustainable development without unacceptable negative impacts. Relevant fields in this context are:

- Biofuels and resource competition.
- Biomass production and logistics.
- Conversion to gaseous and liquid fuels.
- End-use.
- Overall chain sustainability.
- Policy instrument development.

A strategy to achieve sustainability includes the need for certification systems. Developing certification procedures for biomass feedstock to be used in biofuel production requires identification and assessment of existing systems followed by measures taken to improve them. The existing legal framework should be taken into consideration while learning from recent national initiatives. Certification procedures need to be applicable at both global and local level and relate both to small farmers or foresters as well as large conglomerates.

The economic impact of certification on aspects such as product costs also needs to be evaluated.

There is a strong need to improve the database and information required to quantitatively measure sustainability. Existing LCA and other published studies are based on assumptions and projections for different technologies and there are quantitative and qualitative differences in the basic input data that have been used for different studies. Hence, the end results depend on the set of input data and assumptions and often require future validation.

The generation and validation of sets of data to be used for such studies have to be addressed as a part of R&D programmes to be established.

All these objectives can be facilitated by development of a Road Map for the introduction, step by step, of a simple certification scheme.

Policy Measures and R&D

Implementation of policy measures also needs to be supported by specific R&D activities, related to identification and assessment of technical, economic, environmental, and social barriers hindering a wider use of biofuels on a global scale as well as identification and assessment of alternative policy measures resulting in a final package that helps to overcome such barriers.

4. PUBLIC AWARENESS AND SOCIAL ACCEPTANCE

The introduction of a new technology and/or a new product into the market will take time; therefore there is a period during which it may be unfamiliar to the public in general as well as to many of the stakeholders involved during the early stages of development. The length of this introductory period depends on factors such as the nature of the technology or the product, the frame conditions set by government, the economic situation and the environmental impact, as well as other social aspects. As biofuels will probably remain 'policy-driven' in the mid term, societal support for biofuels policy measures is of vital importance for the long-term success of biofuels for transport. Hence, the effects of introducing biofuels need also to be addressed at a societal level.

The benefits, as well as any problems, that may arise from the increased use of biofuels have to be discussed openly within the community as a whole, especially taking into consideration sensitive issues such as:

- Competition between biomass feedstocks for use as food and fodder, raw materials or energy carriers in Europe and worldwide.
- Efficiency and GHG emissions levels for alternative routes and locations of biofuel production.
- Questions raised about potential or perceived problems related to biofuels use.

The current media debate shows a wide range of opinions concerning the significance of the relationship between the increased demand for agricultural raw materials to produce biofuels and current high prices for food commodities, especially cereals and vegetable oils. This clearly illustrates that many potential implications of biofuels use will need to be investigated in depth and the results published and widely discussed at all levels of society. Robust technical and system studies, as well as demonstration activities, will be required to support such discussions.

EU citizens will only be willing to accept the initial financial burden related to an active biofuels policy if they are confident that biofuels are a positive option for transportation and that they bring significant benefits to society, economy and the environment, both inside and outside the EU.

It has to be ensured that public awareness and opinion is based on a sound understanding of the merits of biofuels - then social acceptance will increase as years go by. This requires the right decisions to be taken and all relevant information to be communicated to the public in an accurate manner taking into account the fact that 'negative' or 'disaster' stories frequently appear more attractive to the media than 'success' stories.

If appropriately disseminated, such information could increase acceptance of a new technology and a new product both globally and at the local level, although some resistance will no doubt arise during the planning stage of specific projects.

Social confidence and public acceptance are in general enhanced when relevant studies are carried out by institutes and bodies that are seen to be neutral. Hence, such investigations must be based on sound science providing reliable data, carried out in co-operation with industry and preferably involving other stakeholders including NGOs.

By keeping biofuels regulations clear and consistent and providing transparent information on their beneficial impact on economy, environment and society, public awareness will be increased and social acceptance gained.

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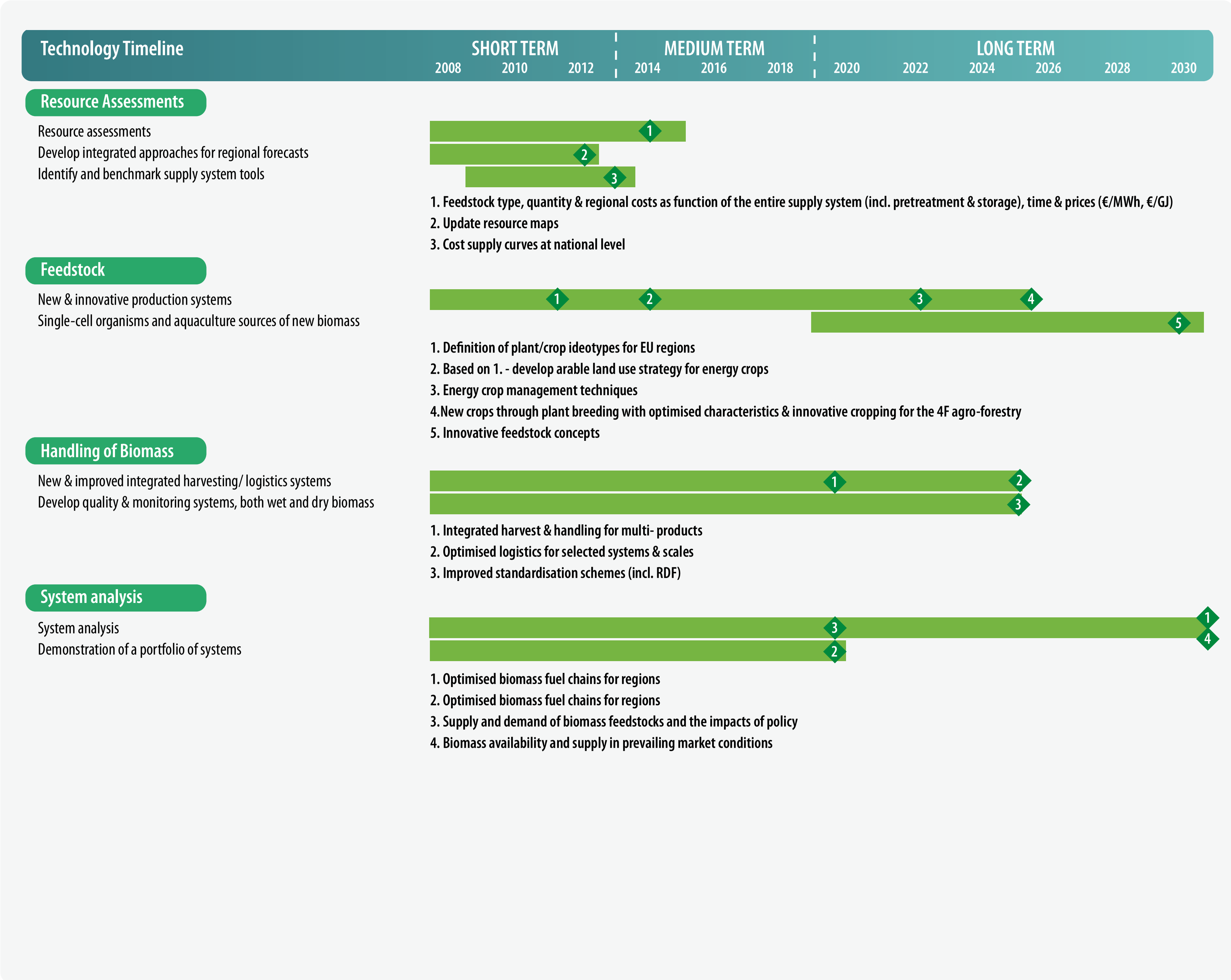
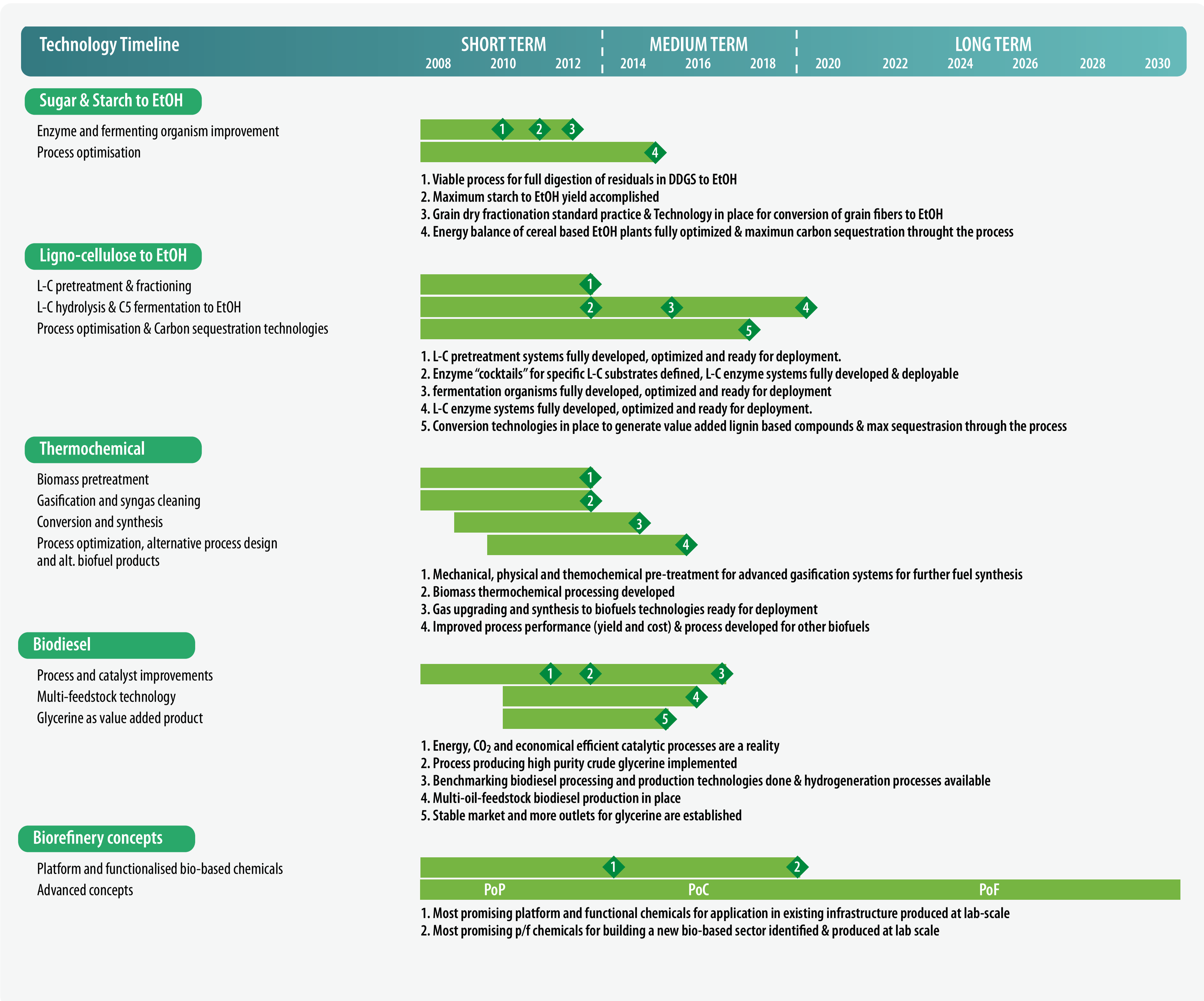
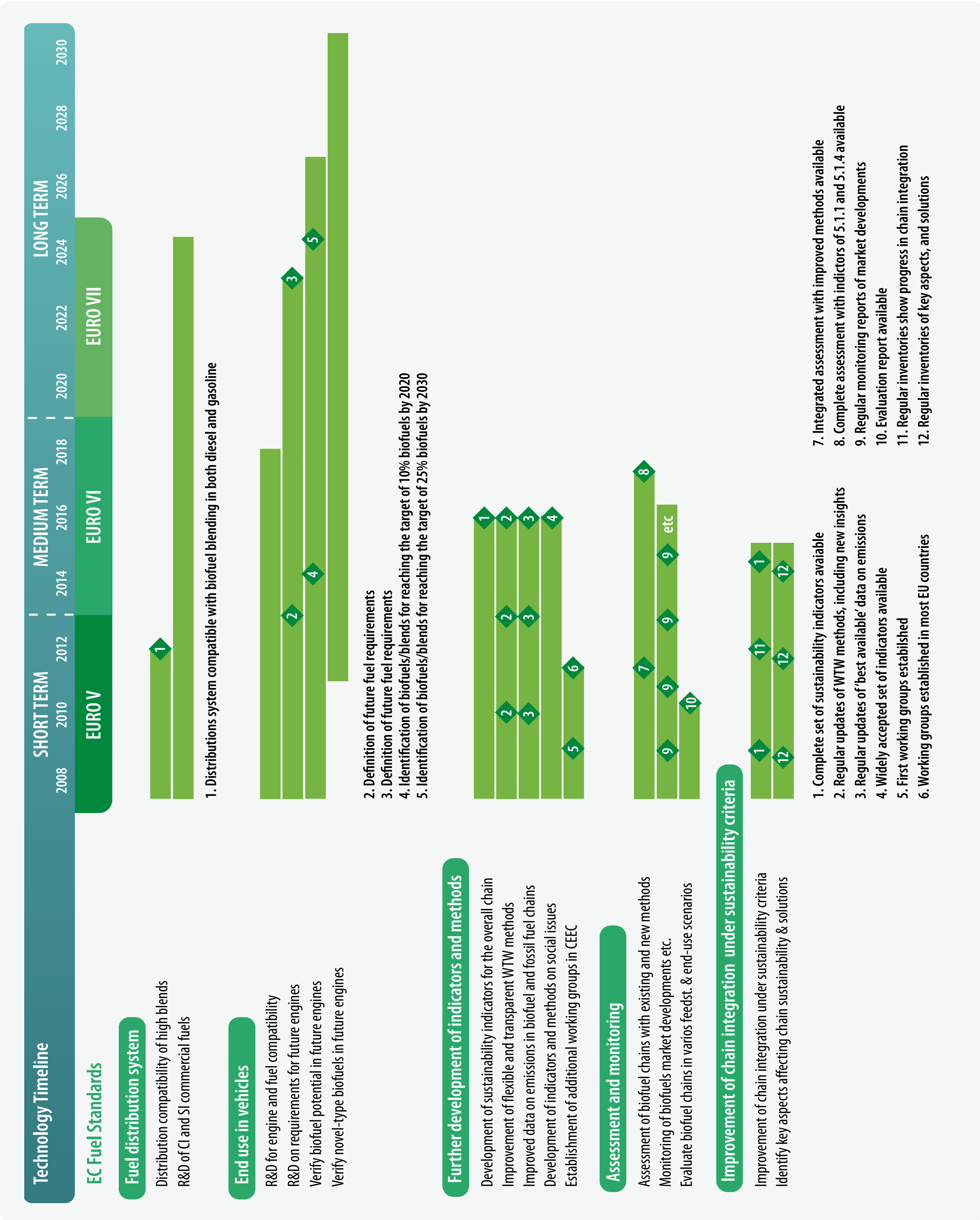
Annex 2. Condensed Roadmap





Annex 2. Condensed Roadmap (continued)



Annex 3. Glossary and Abbreviations

BTL	Biomass-to-Liquid
CI	Compression Ignition
CNG	Compressed Natural Gas
CV	Commercial Vehicle
DI	Direct Injection
DPF	Diesel Particulate Filter
EGA	Exhaust Gas After-treatment
ETBE	Ethyl Ter-Butyl Ether
EUCAR	European Council for Automotive R&D.
FAEE	Fatty Acid Ethyl Ester
FAME	Fatty Acid Methyl Ester, normally referred to as "biodiesel" (as applied in this document)
GHG	Green House Gas(es)
HCCI	Homegeneous Charge Compression Ignition
HVO	Hydrotreated Vegetable Oil
ktoe	kilo tonnes of oil equivalent
LCA	Life Cycle Analysis
LPG	Liquified Petroleum Gasoline
MON	Motor Octane Number
MPI	Multi Port Injection
RME	Rape Seed Oil Methyl Ester
RON	Research Octane Number
SCR	Selective Catalytic Reduction
SET	Strategic Energy Technology (SET Plan by EU)
SI	Spark Ignition
TWC	Three-Way Catalyst
WTW	Well-to-Wheel (i.e. complete production chain including end use)

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