European Biofuels
TECHNOLOGY PLATFORM

# European Biofuels Technology Platform
# Strategic Research Agenda 2010 Update

## innovation driving sustainable biofuels

July 2010

## European Biofuels Technology Platform - Innovation driving sustainable biofuels

The European Biofuels Technology Platform (EBTP) was established in 2006 to contribute to the development of cost-competitive, world-class biofuels technologies, and accelerate the deployment of sustainable biofuels in the European Union, through a process of guidance, prioritisation and promotion of research, development and demonstration activities (R&D&D).

It brings together the knowledge and expertise of stakeholders active in the biofuels value chains: biomass resources providers, biofuels and bioenergy producers, technology vendors, transportation fuels marketers, transport industry, research and technology development organisations and NGOs. It is managed by a Steering Committee and supported by a Secretariat, the European Commission being an active observer. Stakeholders can register and share access to key contacts, internal and external reports, events, opinions and expertise on biofuels R&D. Platform activities are carried out through five working groups (Biomass, Conversion, Logistics and End-use, Sustainability, and Markets and Regulations) and Task Forces on specific topics (European Industrial Bioenergy Initiative/EIBI, Algae).

For more information on the European Biofuels Technology Platform please visit www.biofuelstp.eu

**European Biofuels Technology Platform: Strategic Research Agenda Update 2010**



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# Contents

# Preface

*In January 2008, EBTP presented a collective view[1] of the main Research, Development and Demonstration (R&D&D) priorities and accompanying deployment measures required for a successful implementation of sustainable and competitive biofuels in the EU.*

*This document identified the 3 critical areas in which technology development should play a key role (feedstocks, conversion processes, end-use technologies) and highlighted clearly that the winning options would be the pathways (combination of feedstock, conversion and end products) that best address both strategic and sustainability targets; environmental performance (greenhouse gas reduction, biodiversity, water, local emissions), security and diversification of energy supply, economic competitiveness and public awareness.*

*This 2010 update is strongly rooted in these core findings, which remain fully valid. In view of the EU 2020 climate and energy targets, the purpose of the update is to present a synthetic view of the most significant recent developments (technical and non-technical) of relevance to biofuels, and to highlight corresponding R&D&D priorities. The format is deliberately concise, aiming to present a simple overview of this complex area, rather than claiming to provide exhaustive coverage. It is based on a broad base of collective expertise within EBTP working groups, which gather actors from across the biofuels value chains: feedstock providers, biofuels and bioenergy producers, technology vendors, transportation fuels marketers, automotive industry, aviation industry, research & technology development organisations and NGOs.*

*Over the last 2 years, the EBTP has actively contributed to shaping the European Industry Bioenergy Initiative (EIBI)[2], which will support demonstration[3] and reference plant[4] projects for innovative bioenergy value chains with large market potential via public private partnerships.*

*The EIBI proposal of the EBTP and the present document share common foundations and essential key messages. However, their respective purposes and scopes are distinct. The EIBI proposes a new programme to select and fund projects to accelerate industrial deployment of promising new technologies. The 2010 SRA update, on the other hand, presents a synthetic view on the key issues that drive, shape and enable biofuels developments (regulations, sustainability, feedstocks, technology) to highlight priority areas where further R&D&D is needed.*

*EBTP remains fully committed to an ongoing dialogue with all stakeholders and strongly encourages partnerships between public and private actors to jointly drive innovation for sustainable biofuels.*

***Véronique Hervouet***
***Chair of the Steering Committee, European Biofuels Technology Platform***

[1] *European Biofuels Technology Platform Strategic Research Agenda & Strategy Deployment Document (EBTP SRA/SDD). Available at www.biofuelstp.eu.*

[2] *Boosting the contribution of bioenergy to the European Union Climate & Energy ambitions: a proposal for a European Industrial Bioenergy Initiative (EIBI): Executive summary. Available at www.biofuelstp.eu.*

[3] *Demonstration plant: demonstrates the performance and reliability of all critical steps of the value chain so that the first commercial unit can be designed and performance guaranteed from the outcome of the Demo unit.*

[4] *Reference Plant: first commercial scale unit.*

# 1. Executive Summary

The aim of this update is to present the most significant recent evolutions relevant to biofuels and to highlight corresponding R&D&D priorities

## Facts

- Strong growth of biofuels production and consumption worldwide continued over the last 2 years, including in Europe. This growth is driven by regulations.
- Biofuels economics have been strongly exposed to swings in oil and bio-feedstock prices: the spike in crude oil prices did not allow biofuels to become competitive with fossil fuels.

Biofuels deployment is still directly dependant on adequate regulatory frameworks, both for current biofuels and new value chains[5].

- New EU legislation (Renewable Energy Directive and Fuel Quality Directive) introduces regulatory framework for sustainability and sets 2020 targets for the share of renewables in transport fuels and reduction in Greenhouse Gas (GHG) emissions.
- Sustainability and public awareness, already identified in 2008 SRA/SDD as critical, have growing importance.
- New topics for biofuels R&D have emerged:
  - New resources: algae and other aquatic biomass
  - New technology "bricks": synthetic biology, catalytic chemical conversion
  - New demand: biofuels for air, marine & rail transport

## Observations and recommendations

The fundamentals for biofuels have not changed. As highlighted in the 2008 SRA, the winning options will be the pathways (combinations of feedstocks, conversion processes and end products), which best address combined strategic and sustainability targets: environmental performances (green house gas reduction, biodiversity, water, local emissions), security and diversification of energy supply, economic competitiveness and public awareness.

Currently, commercially deployed feedstocks and conversion technologies should provide a significant contribution to the EU 2020 targets but will probably not be sufficient. It is necessary to enlarge the feedstock basis and enhance conversion efficiency. These broad objectives were at the core of the 2008 SRA/SDD findings and remain fully valid.

- R&D on sustainability related tools and data need higher priority and increased public funding to ensure that sustainability related legislation, standards and certification schemes are rooted in sound science, based on transparent and relevant data, and use practical tools.
- Sustainable and reliable supply of feedstocks will be a critical success factor for the long-term perspective of biomass-based technologies on a large scale. This relates to efforts in improving productivity in these sectors, in developing reliable supply chains that open up the feedstock potentials, certification issues, and prevention of excessive disturbances in agricultural and forest commodity markets. These challenges, which are not specific to bioenergy and biofuels use of biomass, should be addressed in a coherent effort shared with the relevant stakeholders and initiatives.
- For current industrially deployed value chains and technology the R&D focus is on improvement of environmental and economic performance.
- For innovative biofuels value chains (not yet commercially deployed) short/mid term (2020 horizon) applied R&D should focus mainly on supporting pilot, demonstration[6] and first industrial deployment of technologies (reference plants[7]), allowing feedstock flexibility and/or higher added value end products, in full compliance with EU sustainability targets.
- Because of the variety of potential feedstocks at global and EU levels, different conversion technologies are needed based on mechanical, thermochemical, biological and chemical processes.
- The winning options can only be identified taking into account the full value chain from feedstock to end products, for well defined contexts of raw materials, regulations and potential industrial synergies (the "Value Chain" approach, closely related to the "Biorefining" concept). To develop and optimise the use of the European "basket of feedstocks", a "toolbox of technologies" is needed.
- Algae, synthetic biology[8] and chemical/catalytic conversion technologies offer new feedstock and/or technical options for biofuel value chains. They deserve full recognition in the public funded R&D programmes. They already receive considerable attention and funding in North America.

[5] *Value Chain: specific combination of feedstock, processing technologies and marketable end products*

[6] *Demonstration: demonstrate the performance and reliability of all critical steps of the value chain so that the first commercial unit can be designed and performance guaranteed from the outcome of the Demo unit.*

[7] *Reference Plant: first commercial scale unit*

[8] *Synthetic biology: rational design of the metabolism of a micro organism to produce a desired molecule with high yield, and productivity, using modern biotechnology tools.*

- The share of biofuels in the EU market for road transport fuel is rising, with an increasing appetite for distillates to serve markets for transport fuels (road, aviation, marine). Research on feedstocks and/or conversion technologies to serve these fast growing needs should receive enhanced priority.
- Basic research is needed both to support the science underlying ongoing technology developments and to prepare for future, longer term, breakthrough options.
- Value chains leveraging on industrial synergies with existing facilities deserve priority attention as they might offer the best economic and industrial framework to manage the high risk/high cost of deploying promising new technologies, thereby helping the transition from conventional to advanced biofuels.
- The European Industrial Bioenergy Initiative (EIBI), which aims to select and fund demonstration and first industrial deployment of innovative biofuel/bioenergy technologies with large market potential, is critical to boost the commercial deployment of promising value chains to meet EU 2020 targets.
- To prepare the Implementation Plan for EIBI, it is essential to identify realistic and meaningful public funding sources, and to develop pragmatic and efficient governance principles to allow rapid and transparent implementation and give a clear signal to private actors that early movers to industrialise promising but risky technologies will be supported.


**A range of technologies are being developed to convert agricultural residues, such as straw, into advanced biofuels, including BtL and Cellulosic Ethanol**

## 2. Introduction

Since the publication of the 2008 SRA/SDD, the overarching fundamentals for biofuels have not changed and its core findings remain fully valid. However, significant evolution is ongoing and new topics have emerged, with considerable influence on biofuels development and corresponding R&D needs. The purpose of this update is to present a synthetic view of these issues and topics.

Highlighting sustainability, policy framework and public awareness as critical for shaping biofuels markets, this document presents the most significant recent developments in these areas.

The last two years **witnessed strong growth in biofuel production and consumption** – not only in Europe but in several regions of the world. A further increase in global biofuels demand is anticipated because of biofuels regulations being introduced or pursued in many countries.

To date, ethanol has accounted for two-thirds and biodiesel for one-third of total biofuels production. At the same time, biofuel markets have experienced full **exposure to volatilities in crude oil and bio-feedstocks prices**. Figure 1 shows the developments and correlations of crude oil, rapeseed oil and wheat prices between June 2000 and May 2010.

The fundamentals have not changed; commercial deployment of biofuels still depends very much on appropriate **regulatory frameworks**, both for existing biofuels and for innovative value chains.

### EU Directives

Two **recent pieces of EU legislation** (Renewable Energy Directive (RED) and Fuel Quality Directive (FQD)) will have considerable impact on the biofuels landscape in Europe over the next decade. These Directives set targets for the share of renewable energy and Greenhouse Gas (GHG) emissions reduction for transport fuels.

The Directives also frame the basis for sustainability criteria. They validate the urgent need for adequate technologies to broaden the feedstock base and to maximise the economic and environmental efficiency of the entire value chain for current and new feedstocks (biorefining[9]). These goals were already highlighted in the 2008 SRA.

**Sustainability and public awareness**, topics already presented in 2008 by EBTP as critical, have since attracted the full spotlight. This is a reflection of the complexity of biofuels issues, at the convergence of agricultural, energy, climate, environmental, transport, trade and local development policies.

Other low-carbon and renewable energy options do not provide a simple and unique solution to the world's climate and energy challenges, but they are a vital part of the solutions, provided their limitations are recognised and potential drawbacks addressed in the regulatory framework.

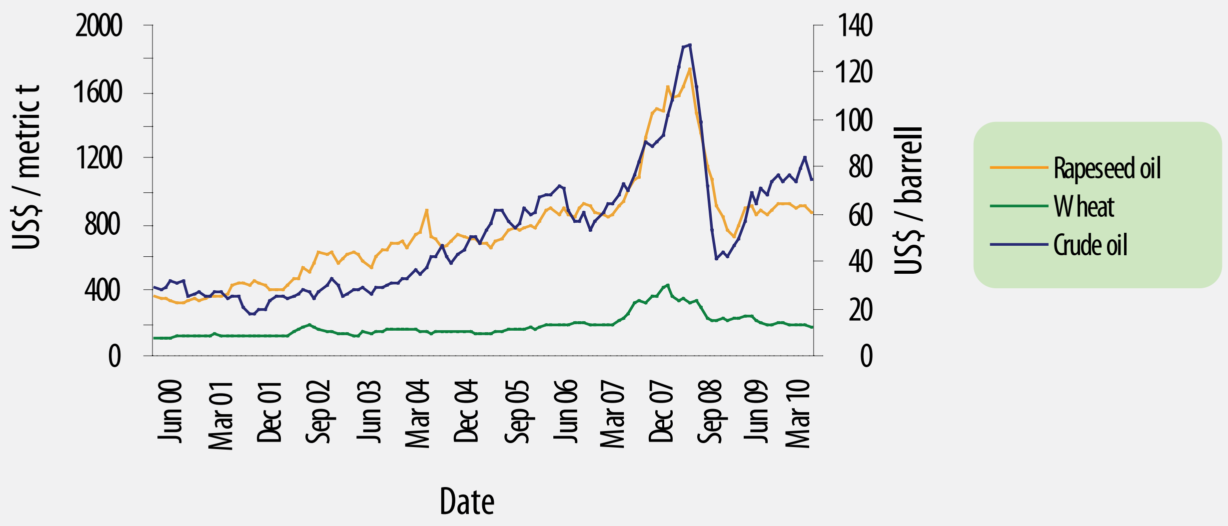



***Figure 1.*** *Correlation between Rapeseed Oil, Crude Oil and Wheat Prices (2000-2010)*

[9] *Biorefining is the sustainable processing of biomass into a spectrum of bio-based products (food, feed, chemicals, materials) and bioenergy (biofuels, power and/or heat) [IEA Bioenergy Task 42 on Biorefineries]*

**New R&D topics** have also emerged:

- upstream with algae as a potentially significant additional biofeedstock,
- midstream around the conversion technologies "tool box" with the emergence of synthetic biology[10] and catalytic process applications for biofuels, and
- downstream with new end markets requesting biofuels; air, marine and rail transportation.

Electrification of transport is one of the hot topics and there is ongoing discussion about the potential contribution of electric vehicles to the market (ERTRAC, 2009). Both electric vehicles and biofuels can contribute to the decarbonisation of transportation by complementing rather than competing with each other (for example, hybrid vehicles). However, biofeedstocks are not directly linked to the market development of electric vehicles. Therefore, they are not included in this document.

In line with the recommendation of the 2008 SRA/SDD to accelerate efforts towards implementation, EBTP has been very active over the last two years in shaping the **European Industrial Bioenergy Initiative EIBI** in the framework of the SET Plan[11].

In this context, the Value Chain Approach was developed by EBTP. This approach makes it possible to identify critical technologies and focus on relevant priorities for public and private actors willing to accelerate the deployment of advanced and sustainable bioenergy. Scope, objectives and activities currently under preparation within EIBI are presented in the final chapter of this document.

## Strategic Energy Technology (SET) Plan

In November 2007, the European Commission presented the European Strategic Energy Technology Plan, SET Plan, COM(2007)723, which was adopted by the Energy Council of Ministers in February 2008 as a basis for the energy technology policy for Europe, which aims at the wide-scale application of low carbon technologies. The SET Plan calls for strategic planning and new governance to align technology development with energy policy goals. Among the tools envisaged for the implementation of the SET-Plan, European Industrial Initiatives are expected to play a critical role. The key features of a European Industry Initiative as presented in the SET-Plan are the following:

- The initiative should not be realistically feasible at national level and should clearly leverage on European scale capability for additional resources and added value.
- It should be industry led, pool public and private financing and share risk via public-private partnership.
- It should be based on the definition and achievement of clear targets with quantified objectives.
- It should boost research and innovation in order to deliver results beyond business as usual.

Bioenergy is one of the 6 priority European Industrial Initiatives proposed initially.

[10] *Synthetic biology: rational design of the metabolism of a microorganism to produce a desired molecule with high yield and productivity, using modern biotechnology tools.*

[11] *The SET-Plan, COM(2007)723 was adopted by the Energy Council of Ministers in February 2008 as a basis for the energy technology policy for Europe, aiming at the wide-scale application of low carbon technologies.*

# 3. Sustainability



## Key facts and recommendations

Sustainability was identified as a key issue by EBTP in the 2008 SRA/SDD

### Main recent evolutions

- Over the last 2 years, recognition of the overarching dimension of sustainability has developed considerably.
- First introduction of legal requirements for sustainability in the EU biofuels legislation in June 2009, with the Renewable Energy Directive (RED) and the Fuel Quality Directive (FQD). Quantitative targets are set for GHG emission reductions. RED and FQD are presented in more detail on page 10.
- Certification criteria are still under development with many open questions (direct and indirect land use, definition of biodiversity, soil, water, social criteria, etc.).
- It is increasingly recognised that sustainability requirements for bioenergy/biofuels use of biomass further restricts its availability, as do competing usages (food, feed, fibre). It is also recognised that adequate sustainability requirements are critical to ensure the long-term availability of biomass.

### Policy recommendations

- Greater EU regulatory clarity and coherence across member states is necessary.
- Continued dialogue at international level is needed to achieve compatible standards.
- Ensure that sustainability criteria are applied across all biomass uses to allow a level playing field and avoid poor sustainability performances in some sectors.

### R&D recommendations

- Practical implementation of sustainability requirements in legislation and the marketplace must be based on relevant, transparent and science-based data and tools:
- Since sustainability of biofuels is still a "loosely defined" topic from a scientific point of view, it is essential to accelerate the development of science based, rational and transparent:
    - Criteria, indicators, methodology (LCA and others) and data,
        - across the full value chains, from feedstocks to end uses
        - for EU relevant geographies, for both domestic and imported feedstocks or biofuels
        - for the three dimensions of sustainability:
            - environmental (GHG, $CO_2$, $N_2$, $CH_4$, water, biodiversity, local emissions, soil, etc.)
            - social
            - economic
    - Models, monitoring and impact assessment tools to:
        - help assess the implementation of enacted legislation
        - prepare public (policy) and private (investment) decisions
        - better asses the issues around direct and indirect land use change
        - help manage the issues of competing uses of arable land and biomass.
- A better understanding of sustainability aspects of biofuel value chains versus other economic "value chains", as well as non-market "common goods", is needed, in particular to include systemic impacts over short versus long term time lines.
- Sustainability-related tools and data should be a priority for public funded R&D at EU and national level

## Main recent evolutions

Sustainability was already identified as a key challenge for biofuels by the EBTP in the original 2008 SRA/SDD. Over the last 2 years, the recognition of the overarching dimension of sustainability has further increased. Since 2008, fuelled by public debates on the potential benefits and drawbacks of biofuels, the issue of sustainability has been taken up by many different public organisations including the European Commission, several Member State administrations, standards bodies such as the CEN and ISO, and also by private actors such as the Roundtable for Sustainable Biofuels.

With the Renewable Energy Directive (RED) and the Fuel Quality Directive (FQD), legal requirements for biofuel sustainability were introduced in the EU in June 2009. These directives set quantitative targets for GHG emission reductions. Although these directives provide a certain legal framework for biofuels, sustainability certification criteria are still under development. Many questions e.g. regarding direct and indirect land use or the definition of biodiversity, soil, water social criteria remain open until today.

It is increasingly recognised that sustainability requirements for bioenergy/biofuels restrict biomass availability, as do competing usages (food, feed, fibre). It is also recognised that adequate sustainability requirements are critical to ensure the long-term availability of biomass.

## Policy recommendations

Greater EU regulatory clarity and coherence across Member States are necessary. In addition, continuous dialogue at international level, including NGOs, is needed to achieve compatible standards. Finally, sustainability criteria should apply to all biomass uses to allow a level playing field and avoid poor sustainability performance in other sectors.

## R&D recommendations

Practical implementation of sustainability requirements in legislation and market place must be based on relevant, transparent and science-based data and tools.

Since sustainability of biofuels is still a "loosely defined" topic from a scientific point of view, it is essential to accelerate the development of science-based, rational and transparent criteria, indicators, methodology (e.g. Life Cycle Analysis) and data. Such methodology should be applied to the full value chain (from feedstocks through conversion processes to end uses), to EU-relevant geographies (production in places relevant to EU-markets for both domestic and imported feedstocks and biofuels) and to the three dimensions of sustainability (environmental[12], social and economic).

It is also necessary to develop science-based, rational and transparent models, monitoring and impact assessment tools to help evaluate the implementation of legislation and to facilitate public (policy) and private (investment) decision-making. In addition, such evaluation tools must take into account the issues of direct and indirect land use change, of competing uses of arable land, and the use of degraded, abandoned and contaminated land for biomass production.

Moreover, a better understanding of sustainability aspects of biofuel value chain versus other economic "value chains" as well as non-market "common goods" is needed, in particular to include systemic impacts over short versus long term time lines. Sustainability-related tools and data should be a priority for public R&D funding at EU and national level.

[12] *GHG, $CO_2$, $N_2$, $CH_4$, water, biodiversity, local emissions, soil, etc.*


***R&D&D Needs on Sustainability Assessment***

*The column to the left of the green bars indicates the research topics. Research objectives are indicated by the numbers in the bars and are described below. The placement of the numbers indicates the estimated time of achievement.*

# 4. Markets, regulatory framework & public awareness

## Key facts and recommendations

### Main recent evolutions

- Sharp increase in biofuel production and consumption in the EU and worldwide, despite public controversy over potential pitfalls of biofuels such as "food vs. fuel" and GHG balance.
- Despite high oil prices, biofuels have not become competitive with fossil fuels because agricultural commodity prices also followed the price surge. Biofuels still require regulatory support to compete on the market.
- The Renewable Energy and Fuel Quality Directives (RED and FQD) provide a regulatory framework for biofuels in 2020 in the EU.
- Member States implementation of the above directives is expected to provide greater clarity on renewable fuel and energy mix targets at national levels. However, the current lack of clear EU sustainability requirements creates investment and market uncertainty.
- Different regulatory frameworks, including sustainability requirements and support for advanced technologies, are being more actively developed in some countries (The Netherlands, UK, Germany, US/RFS2, California). Low-carbon requirements and market incentives focus, so far, essentially on GHG performance.
- The complexity of biofuel issues is not yet fully understood by the public.

### Policy recommendations

- Favour a pragmatic approach to EU biofuel legislation, starting with simple, meaningful, quantifiable and verifiable criteria, based on sound science. Ensure a swift implementation at Member States level.
- To support RED and FQD, easy-to-operate land use change and other sustainability criteria must be further clarified.
- For innovative biofuel technologies, ensure continued R&D support through existing EU and national instruments, and develop relevant investment schemes (grant, loans, fiscal incentives) to allow funding of risky demonstration and reference units via public/private partnerships (see chapter 9 on EIBI).
- Increase public funding and strengthen support of R&D on sustainability related tools and data.
- Encourage and support initiatives to inform and explain to the wider public the benefits of biofuels and the ongoing efforts to minimise their pitfalls.

## Main recent evolutions

Despite public controversy over biofuels, production and consumption in the EU and worldwide increased sharply over the past years, driven by regulations.

The global biofuels supply reached 34.1 Mtoe in 2007, an impressive 37% rise compared to 2006. Most of the increase in biofuel usage in 2007 and 2008 occurred in the OECD countries, mainly in North America and Europe[13]. In Europe, 10 Mtoe of biofuels were consumed in 2008. This equals 3.3% of all road transport fuel (energy content)[14]. Ethanol accounted for two-thirds and biodiesel for one-third of the total biofuel production (see figure 3).

In recent years, prices for both crude oil and agricultural commodities have been highly volatile. This has impacted on the economic profile of biofuels. While rising oil prices tend to increase the competitiveness of biofuels, this was offset by higher prices for agricultural commodities. Thus, even though the first European countries started to introduce biofuels 15 – 20 years ago, biofuels are not yet ready to compete on the market without adequate regulatory support (except bioethanol in Brazil).

[13] *IEA, World Energy Outlook 2009, p. 87 IEA, World Energy Outlook 2009, p. 87*

[14] *EurObserv'ER, Biofuels barometer, Edition 2009, p. 55*

[15] *Official Journal of the European Union of 5 June 2009*

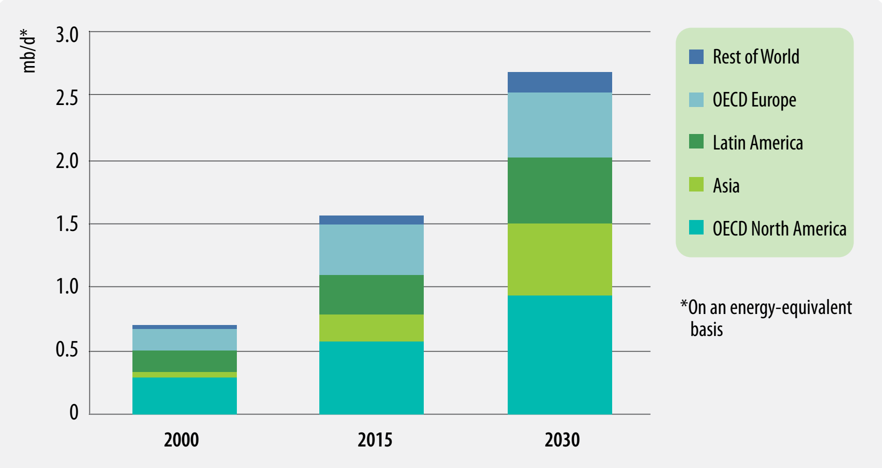



***Figure2:*** *Biofuel demand by region (Source: IEA, World Energy Outlook 2009, p. 88)*

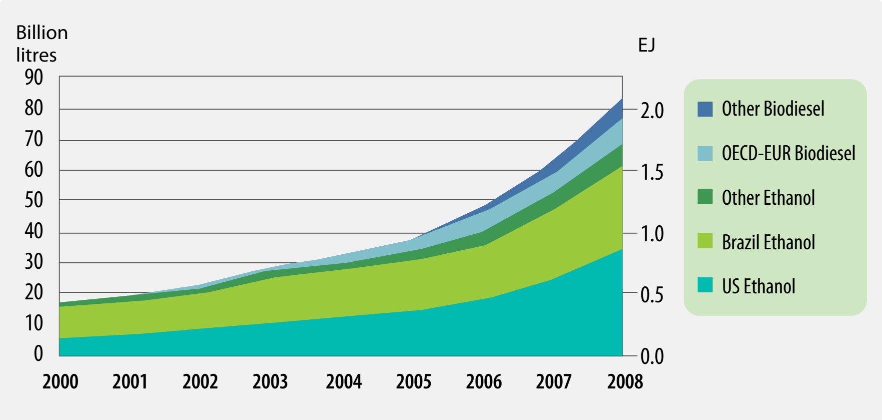



***Figure 3:*** *Global biofuel production 2000-2008 (Source: Sustainable Production of 2nd Generation Biofuels - Potential and perspectives in major economies and developing countries © OECD/IEA 2010, p. 22)*

The Renewable Energy and the Fuel Quality Directive provide the legal framework for biofuels in the EU. Member State implementation of these directives is expected to provide greater clarity on renewable fuel and energy mix targets at national level. However, the current lack of clear EU sustainability requirements creates investment and market uncertainty.

Different regulatory frameworks including sustainability requirements and support for advanced technologies, are being developed more actively in some countries (Netherlands, UK, Germany, US/RFS2, California). Today, low-carbon requirements and market incentives focus essentially on GHG performance.

The complexity of biofuel issues is not yet fully understood by the wider public.



## Renewable Energy Directive 2009/28/EC[15]

- By 2020, mandatory targets of 20 % share of RES in final energy consumption, 20 % increase in energy efficiency and 10 % of RES in transport in each Member State.
- Harmonised approach with Fuel Quality Directive
- No biofuels from carbon rich or bio-diverse land. EC has to report on compliance with environmental and social sustainability criteria of major biofuel exporting countries.
- Minimum GHG reduction for biofuels of 35% and 50% from 2017 onwards, and 60 % for new installations from 2017 onwards. For plants already operating in January 2008 GHG requirement will start in April 2013.
- Bonus of 29g $CO_2$/MJ for biofuels from degraded/ contaminated land.
- Biofuels from waste, residues, non food cellulosic material, and lignocellulosic material will count twice for RES transport target.
- Member State Implementation into national legislation by December 2010.

## Fuel Quality Directive 2009/30/EC

- Further tightening of environmental quality standards for a number of fuel parameters.
- Enabling more widespread use of ethanol in petrol (E10) with transitory regulations (protection grade E5) for older cars and derogations for petrol vapour pressure, subject to EC approval.
- Increase of allowed biodiesel content in diesel to 7% (B7) by vol., with an option for more than 7% with consumer info.
- Introducing a mechanism for reporting and reduction of the life cycle GHG emissions from fuel.
- Reduction in life cycle GHG emissions from energy supplied. Binding target of 6% between 2011-2020 as first step, while leaving open the possibility to increase future level to 10 %.
- In a 2012 review, the Commission will need to assess a further increase of the level of 2% from other technological advances, such as the supply of electricity for use in transport. A further 2% is envisaged by the use of CDM credits for flaring reductions not linked to EU oil consumption.

## Recommendations

A pragmatic approach to biofuel legislation is thus vital on an EU level. Such legislation should be based on simple, meaningful, quantifiable and verifiable criteria which are based on sound science and which are implemented without delay at Member State level.

To support RED and FQD, land use change and other sustainability criteria must still be further clarified.

For innovative biofuel technologies, continued R&D support must be ensured through existing EU and national instruments. Moreover, high-risk demonstration and reference plants require adequate investment schemes (grant, loans, fiscal incentives) to allow funding e.g. via public/private partnerships (see EIBI, chapter 9).

It is also necessary to increase public funding and to strengthen support of R&D on sustainability related tools and data (see chapter 2).

Finally, initiatives to inform and explain to the wider public the benefits of biofuels and the ongoing efforts to minimise their pitfalls need shall be encouraged and supported.

## Public awareness

Since their early introduction in the EU in the 1990's, biofuels have been presented as a green substitute for oil-derived fuels and have benefited from an overall positive image. During 2008, as food prices soared, media attention focussed on biofuels as the perceived main reason ("food vs. fuel" discussion).

Questions were asked as to how much land would in future be taken up by biofuel/bioenergy production, and thereby lost for food production. It was also pointed out that higher food prices would hit the poorest countries the hardest, as people in such countries tend to spend a higher share of their income on food. However, higher food prices can also lead to higher income for smallholders (farmers) who rely on cash crops for their livelihood.

Public discussion on this topic tended to disregard major influences on demand structures, such as diets in developing and industrialising countries becoming richer in animal-based food, or increased price volatility on commodity markets. Several organisations are currently working to quantify the impacts of biofuels on food prices and poverty, besides other aspects such as supply and speculation[16] (see reference list in Annex).

Environmental and social issues related to biofuels also remained high on international agendas in the recent past. Are biofuels carbon positive, negative or neutral? How do they affect biodiversity, water resources and land use patterns? On the other hand, the creation of new business opportunities, potential for rural development and independence from fuel imports are viewed as positive outcomes of biofuels. However, these are not necessarily communicated as strongly to the general public.

It is clear that public awareness of biofuels is crucial to their deployment, and that there can be no acceptance without sound, science-based information communicated in a clear and simple way.

It is critical to encourage and support communication initiatives aiming at explaining to the wider public the benefits of biofuels as well as their potential pitfalls and the efforts deployed to mitigate them.

[16] *For example, the latest DEFRA study (January 5th 2010) concluded that "available evidence suggests that biofuels had a relatively small contribution to the 2008 spike in agricultural commodity prices" (http://www.defra.gov.uk/foodfarm/food/security/price.htm)*

# 5. Biomass availability and supply

## Key facts and recommendations

Increasing the amount of biomass available under sustainable conditions was already identified as a critical challenge for biofuels in the 2008 EBTP SRA/SDD.

### Main recent evolutions

- Wider recognition that availability of sustainable and competitive biomass supply is a first priority issue for biofuels (towards the EU 2020 targets). This is true for all value chains, because no EU feedstock source has been identified that could satisfy all requirements.
- It is now also widely recognised that biomass as feedstock for current and advanced biofuels competes with a range of other end uses (feed, food, paper, wood products, biomaterials, heat, electricity).
- The Renewable Energy Directive (RED) gives residual feedstocks and wastes (agricultural, forestry, industrial and municipal) an advantageous profile, as they provide GHG emission savings without competing for finite land resources.
- Global trade in unrefined feedstocks grows (e.g. vegetable oils, wood pellets).

### Policy recommendations

- Future policy & implementation strategies should enhance complementarity and synergies among different sectors using arable land and/or biomass.

### R&D recommendations

- Develop a common view on sustainable biomass availability across different sectors, shared with all relevant stakeholders.
- Develop cost supply curves for existing and new feedstocks and given timeframes, regions and demand types. Define obstacles to mobilisation.
- Develop new plant varieties (crop/tree breeding and physiology); improve cultivation and management practices (propagation, cultivation systems, etc) to optimise water, energy and other inputs and increase productivity.
- Optimise associated equipment to minimise logistics chain costs and to meet conversion requirements (integrated harvesting, collection and transport solutions for fibre/bio-materials and energy).
- Develop large-scale logistics for new feedstocks or underutilised resources, optimise along the supply chain.
- Competition in biomass use. Research should focus on defining the methods and criteria to assess what types of biomass can contribute to a sustainable biofuels market without directly competing with other uses (particularly food).
- Use of wastes and residues – maximising efficiency of closed-loop cycles and biorefining.

## Main recent evolutions

The availability of sustainable biomass sources is increasingly recognised as the most critical requirement for biofuels to contribute to EU 2020 targets. This is true for all value chains, because no single EU feedstock source has been identified that could satisfy all requirements.

In the EU, biomass and biowaste account for 66 % of the total renewable energy consumption (98 million tons oil equivalent (Mtoe) in 2008), or 5 % of the total energy consumption. Solid biomass represents the main share of this (70 Mtoe), with the rest provided by biogas, transport biofuels and organic, solid municipal waste[17].

It is now also widely recognised that biomass as feedstock for conventional and advanced biofuels competes with a number of other end uses (feed, food, paper, wood products, biomaterials, heat, electricity, etc.). The production of biomass may also be complementary to other uses.

Recent debates over 'food or fuel' have led to an increasing interest in biomass from waste and residues as biofuel feedstock. Moreover, the focus in biofuel support is shifting from simple volume production to GHG saving, making waste materials all the more favourable.

The use of advanced biofuels or those from residues and wastes is expected to reduce feedstock demands, in the case

[17] *EurObserv'ER (2009): The State of Renewable Energies in Europe, Edition 2009*

of the former due to higher net fuel yields per hectare, and in the case of the latter because fuel derived from organic wastes is counted double under the RED. The RED gives residual feedstocks and wastes (agricultural, forestry, industrial and municipal) an advantageous profile, as they provide GHG emission savings without competing for finite land resources.

Furthermore, growth continues in local trade of unrefined feedstocks, such as wood pellets and vegetable oils[18].

## R&D recommendations

Sustainable and reliable supply of feedstocks will be a critical success factor for the long-term development of biomass-based technologies on a large scale. This relates to efforts in improving productivity in these sectors, in developing reliable supply chains that open up feedstock potential, certification issues, and prevention of excessive disturbances in agricultural and forest commodity markets. These challenges, which are not specific to bioenergy use of biomass, should be addressed in a coherent effort shared with relevant stakeholders and initiatives. The priorities mentioned in the following paragraphs have been aligned with Plants for the Future and the Forest-based sector Technology Platform.

Current estimates regarding the worldwide potential of industrial biomass production by 2050 vary considerably, with figures up to 1500 EJ being quoted for the technical potential, while a more realistic range is usually given as lying between 200 and 500 EJ. A majority of this potential is seen in developing countries and emerging economies. If a number of sustainability criteria (environmental, economic and social) are taken into account, variation increases further. Different studies at European level have also resulted in very different predictions with regard to land available for biomass production (19 – 50 million hectares in the EU 27) and with regard to energy crop yields (1 million ha correspond to 2 - 10 Mtoe, depending on the feasible yield at local level).

It is also important to **develop cost-supply curves** for existing and new feedstocks and given timeframes, regions and demand types. This should first cover the EU 27, but later be extended to potential trading partners, such as Brazil, Russia, Ukraine, etc. Common datasets of the major European and international research institutes would increase the credibility of data used by different modelling groups. In addition, obstacles to biomass mobilisation need to be identified.

The overall goals in the field of **plant breeding** are resource efficiency with regard to efficient cultivation systems for energy crops (minimal input / maximal output), yield stability in different environments and environmentally benign cropping systems. Screening of new plant species for use as bioenergy plants is also relevant (biodiversity); however, such species need to show superior characteristics compared to conventional crops. Plant breeding has already resulted in highly efficient crops, and these should be used as a basis for further improvements. In the long run, plant breeding should strive for product properties which facilitate optimised pre-treatment and processing.

With regard to **efficient energy crop cultivation systems**, the aim is to develop and implement land use options. These alternatives must minimise negative impacts (i.e. on biodiversity, water use efficiency) and be flexible in the face of likely climate change. The options can include double cropping and multifunctional land use, as well as innovative concepts which explore issues such as marginal land utilisation.

Harvesting and transport technologies and systems should be adapted and optimised, as minimising logistics costs and meeting conversion requirements (integrated harvesting, collection and transport solutions for fibre/bio-materials and energy) are of major importance to the sustainability of the processing chain. To achieve these aims, there may be a need to develop and adapt specific machinery for biomass optimization and improve biomass transport to processing plants. It is also necessary to develop large-scale logistic concepts for new feedstocks or under-utilised resources and to optimise them along the supply chain.

Regarding the **handling and trading of biomass**, better knowledge of biomass feedstock properties and some universal definitions can play a key role. This includes the development of feedstock quality data (biochemical, 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, as well as safety and standardisation issues covering the full supply chain. The development of physical and chemical pre-processing methods (including blending and fractionation), systems and strategies to provide homogeneous feedstock for large-scale applications is also important in order to help meet the quality requirements of downstream conversion technologies.

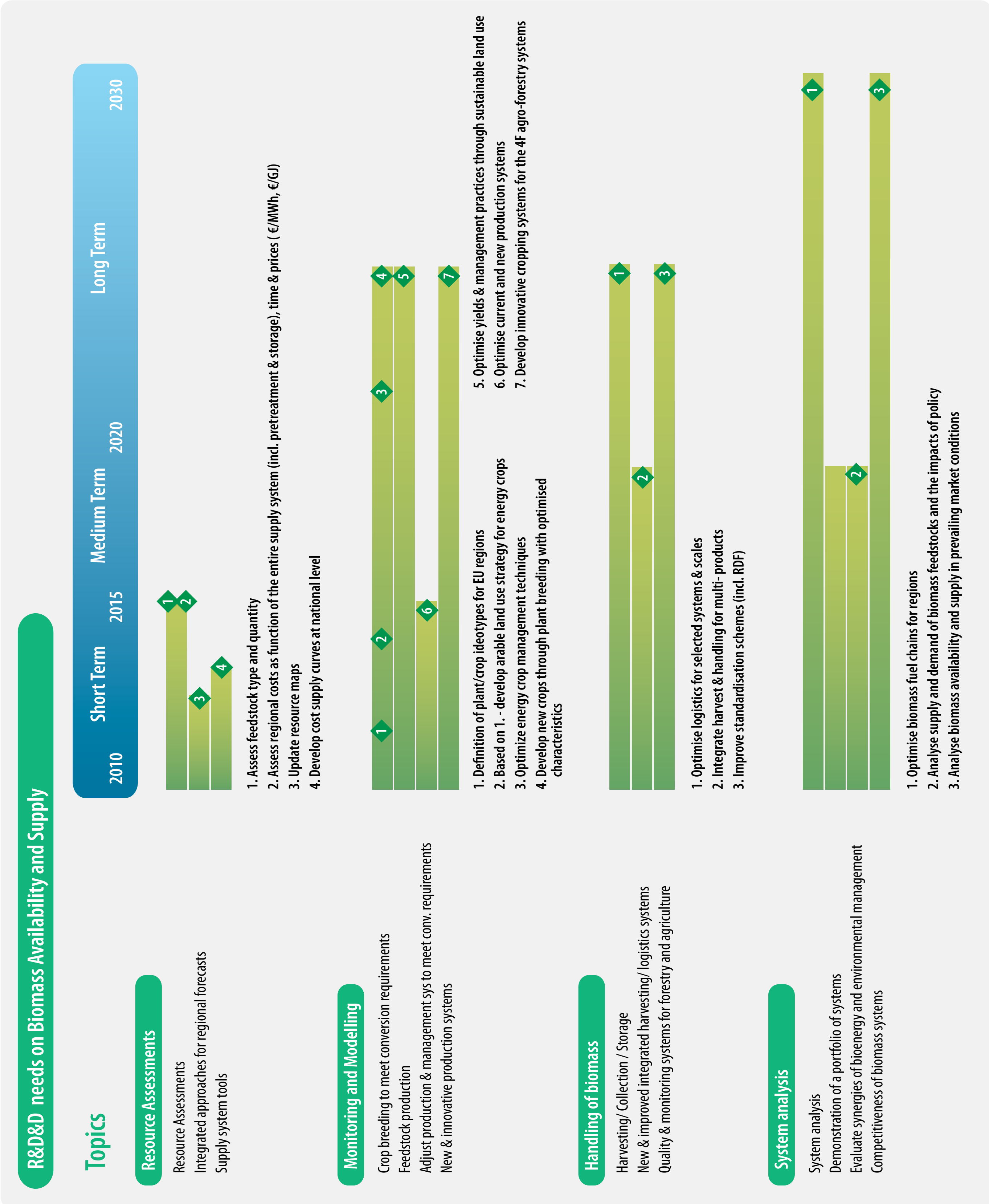
**Sustainability issues,** such as competing and changing land use, and soil and water protection will play a key role in determining crop types, locations and production methods. Relevant regulations are included not only in the cross compliance requirements of the Common Agricultural Policy, but also in the sustainability and GHG provisions of the RED. The wider balance of the carbon sink dimension of forests, conventional forest products and soil husbandry needs to be better evaluated to ensure optimal GHG benefits.

**System analyses:** Supply and demand interactions and the impacts of policy and legislative mechanisms (national, EU and global level) need to be analysed and understood for all biomass feedstocks to avoid unintended consequences. At the same time, a portfolio of systems (suitable for a regional ecology, land ownership and climate) with a high potential for feedstock supply should be developed.

On the issue of competition for biomass, research should focus on defining the ways and the criteria to assess which biomass can contribute to a sustainable biofuel market without directly competing with other uses (esp. food).

Finally, it will be necessary to optimise closed-loop cycles and biorefinery concepts for the use of wastes and residues in order to develop advanced biomass conversion technology / systems and to identify synergies between fuel generation and fully established industries.

[18] *For example, IEA Bioenergy Task 40 http://www.bioenergytrade.org/*




***R&D&D Needs on Biomass Availability and Supply***

*The column to the left of the green bars indicates the research topics. Research objectives are indicated by the numbers in the bars and are described below. The placement of the numbers indicates the estimated time of achievement.*

# 6. Biofuels from Algae

## Key facts and recommendations

Algae have recently emerged as a potential feedstock source for biofuels.

### Main recent evolutions

- Until recently, industrial application of algae has focused solely on high-value products.
- Both micro and macro algae have attracted attention from a biofuels perspective.
- Very little is known so far about the more than 30000-40000 classified species of microalgae.
- Theoretical calculations show attractive potential for future algae-based biofuels, but cost reduction and scale-up are critical challenges.
- As for conventional starch and vegetable oil based biofuels, the competitiveness of algae-based biofuels will strongly depend on the commercialisation of algae co-products.
- A number of pilot and a few demonstration facilities have been built or are in the planning stage, but there are no industrial-scale plants for biofuels from algae yet.
- Extensive R&D&D is underway on algae biofuels worldwide, especially in North America and Europe with a high number of start-up companies developing different options.
- Lipid-rich algae have the potential for use as feedstock for diesel and jet fuels.

### R&D recommendations

- As for other biofuels value chains, it is necessary to take a complete chain/biorefining approach with an integrated appreciation of economic, social, technical and environmental issues.
- R&D (short/mid-term applied and long-term fundamental research) efforts should target efficient, sustainable and integrated growing, harvesting, logistics, conversion and by-product utilisation (with a similar biorefining approach to other biofuel value chains).
- Fundamental research on identification and optimisation of algae strains (micro and macro algae) is needed. Optimisation does not only refer to yield rates, but also to increased tolerance of contaminants.
- Applied R&D is needed to optimise robustness and production scale of algae strains while again increasing tolerance of contaminants.
- Applied R&D on conversion processes, leveraging on existing biofuels conversion technologies where possible.
- Work on sustainable industrial-scale algae production techniques and best practice is required. Main challenges: ensure cost-competitiveness with fossil fuels, improve energy balance, manage large quantities of water, prove scalability.
- LCA and energy balance of algae-to-biofuel production chains, with identical approach to other biofuel value chains.
- Identification and management of environmental externalities of large-scale algae cultures.
- Evaluate advantages and disadvantages of open pond systems versus closed loop bioreactors.
- Evaluate benefits and risks of GMO, including public awareness as well as potential impact on biodiversity. Use of wastes and residues – maximising efficiency of closed-loop cycles and biorefining.

## Main recent evolutions

Algae are unicellular microorganisms, capable of photosynthesis. They are one of the world's oldest forms of life, and it is believed that fossil oil was largely formed by ancient micro-algae.

Since the 1950s algae have been grown commercially, to produce fish food, human food additives and pigments, in ponds or closed photo-bioreactors. Thus far, algae biotechnology research has focused on high-value products (chemicals, cosmetics, food industry) rather than energy uses. Cultivation of algae for fuel purposes is still in the R&D phase, and there is no established commercial production of algal biofuel. Estimations regarding the number of existing algae species vary considerably, between 36000 and 10 million. Of the 30-40000 micro-algae species described so far, fewer than 100 have been tested or used for industrial purposes.

It has been estimated that micro-algae could produce several times more oil than the oil palm, the most productive terrestrial plant. Most scientific literature suggests an oil production potential of between 25-30 ton $ha^{-1}$ $year^{-1}$ and 50 ton $ha^{-1}$ $year^{-1}$ for relevant algae species. Micro-algae contain, amongst others, neutral lipids (tri-, di-, monoglycerides, free fatty acids), polar lipids (glycolipids, phospholipids), wax esters, sterols and pigments.

The most common fatty acids in micro-algae are the chain lengths between C16 and C18. Some algae are reasonably rich in C10, C12 and C14, while PUFAs and other unsaturated fatty acids are produced by several micro-algae species. Yields in fatty acids from micro-algae production for biofuels depend on the medium and nutrients present in the culture. The total lipid content in micro-algae varies from 1 to 90% of dry weight, depending on species, strain and growth conditions. The lipid content of cyanobacteria is generally low, varying between 4–12% of dry weight. Carbohydrate-rich algae have the potential for use as feedstock in biogas production.

Micro-algae are considered as a potential feedstock for biofuel production because they produce lipids through photosynthesis, i.e. using only $CO_2$, water and sunlight. Algae can be grown on non-agricultural land, most of them do not require fresh water, and their feedstock potential is high.

In addition to micro-algae, aquatic environments are inhabited by macro-algae (=seaweeds), some of which may reach considerable sizes. Cultivated macro-algae can be used for fertilisers, for human consumption and for high-value products such as cosmetics and pharmaceuticals. Macro-algae cultivation is an established, viable industry in some parts of the world, mainly Asia. Cultivation is usually and currently based on quite simple technologies. Uncultivated macro-algae can reach yields 2.8 times higher than those of sugar cane (per unit area), while the cultivated *Laminaria japonica* has been shown to exceed 150 t $ha^{-1}$ over a seven month period. The use of macro-algae in biofuel production is focused mainly on bioethanol production, due to their low lipid content (1.3 to 7.8% of dry weight).

## R&D recommendations

Research needs to cover the full range of topics from basic biology to engineering.

The ecology of algae, their **lipid productivity, growth rates and growth control** have to be developed and optimised by screening new or existing strains as well as by molecular biology. Optimisation of algae does not only refer to yield rates, but also to increased tolerance of contaminants. As for other biomass sources, genetic modification would require substantial further R&D, which should be accompanied by thorough risk-benefit analysis and by sustainability assessments which take into account public concerns. At the moment, European legislation on GMO is strict, and does not allow GM microbial production in systems susceptible to leakages.

**Scale-up** is a critical issue for algae production. Even if algae growth and lipid production can be controlled at laboratory scale, there is a clear need for industrial experience in long-term, outdoor, large-scale production of algae lipids. A number of pilot and demonstration facilities are operational or in the planning stage both in Europe and North America, but the economic viability of such operations needs further proof.

Moreover, as **water is a vital resource** for algae production, the use of seawater, as well as technologies for water recycling, especially waste water and eutrophic water bodies, deserve research attention. The use of waste water, which can be rich in nutrients and organic matter, could also decrease or make unnecessary the use of fertilisers. Technologies to recycle nutrients (N & P) will also be necessary as, generally speaking, the use of fertilisers should be minimised or avoided, as it would compete with demands from other production systems, namely food production.

One of the main R&D challenges is to facilitate the sustainable cost-competitiveness of "algae fuel". This will include identifying algae species with high oil content and with higher yields, but also developing and optimising different steps in the cultivation process. The advantages and disadvantages of open pond systems versus closed loop bioreactors also need to be evaluated.

6

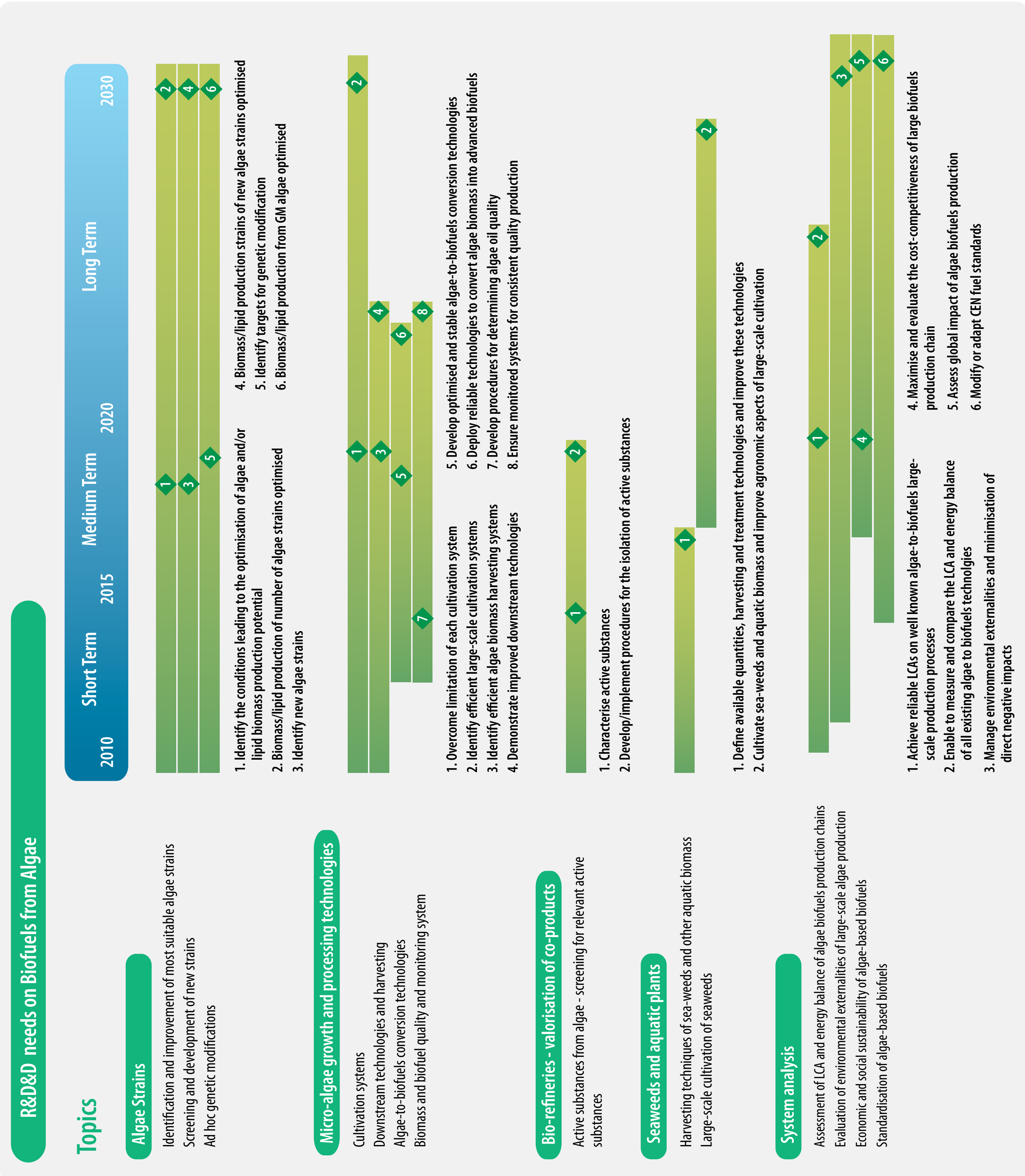
**Efficient cultivation reactors** will have low material costs, and active R&D is already taking place in this area. Low-cost **harvesting technologies** are still in their infancy, with floating, filtration, flocculation and energy-efficient centrifugation under scrutiny. Choice of algae species also influences harvesting, which emphasises the need for collaboration between ecologists and engineers. The **energy balance** of both cultivation and drying must be improved. **Logistics and site selection** are other important questions with regard to a cost-efficient algae production.

Future R&D should ensure a whole **value chain approach.** This encompasses economic, social, environmental and technological appraisals as well as the integration of different valorisation cycles (biorefining) and LCA optimisation. The development of "mild" extraction methods, which would allow both lipid and protein extraction from the same biomass, is one example for such an approach.

Short and medium-term R&D should focus on applied research and demonstration, with efficient and environmentally acceptable production, harvesting, logistics, conversion and by-product utilisation as core topics. Fundamental research will have a longer time horizon, focussing on screening, optimisation or improvement of algae strains for biofuel production. The identification and management of environmental externalities of large-scale algae cultures pose further key challenges.

The aforementioned issues generally apply to both micro and macro-algae. For macro-algae specifically, it will also be necessary to increase the efficiency of post-processing stages such as fermentation/digestion, and to further develop the concept of open-sea cultivation connected to designated structures or existing infrastructure.

For all types of algae, the core aim will be to achieve biorefinery technologies which enable algae to be grown for food, pharmaceuticals and biofuels at the same time.




***R&D&D Needs on Biofuels from Algae***

*The column to the left of the green bars indicates the research topics. Research objectives are indicated by the numbers in the bars and are described below. The placement of the numbers indicates the estimated time of achievement.*

# 7. Conversion processes

## Key facts and recommendations

The key objectives for biofuel conversion technologies were highlighted in the 2008 SRA/SDD; developing energy- and carbon-efficient biomass-to-fuel processes that are flexible with regard to feedstocks and that result in high-quality end products.

### Main recent evolutions

- Due to the many different feedstocks used for different biofuels, different processing technologies are needed. It is not possible to identify "best" technologies outside of a specific value chain and context (e.g. available feedstocks, targeted end products, industrial synergies).
- In the "tool box" of technologies for biomass conversion into biofuels, new tools (previously developed for other applications in the pharmaceutical and chemical industries) have emerged; synthetic biology[19] and catalytic/chemical conversion. These target biofuels with improved technical properties allowing higher blends and compatability with existing infrastructures and engines, which could result in a higher value.
- New biofuel technologies have entered the market place in the EU in recent years, e.g. hydrotreatment of vegetable oil.
- Several new pilot and demo units for advanced biofuels (see information box below) have been built and started up since 2008 SRA/SDD, significantly more in North America than in the EU, whose technology leadership on this topic is increasingly being challenged.

### R&D recommendations

- Key priority for commercial biofuel technologies: improve environmental (GHG, energy balance, water, inputs, etc) and economic performance.
- For advanced biofuels (not yet commercially deployed), the focus is on:
  - Ability to process a wide range of sustainable feedstocks while ensuring energy and carbon efficient process and selectivity towards higher added value products.
  - Biofuels that perform at least as well as, but preferably better than, existing ones. Compatibility with existing fuel infrastructures at increasing blend rates should be aimed at.
- Conversion technologies targeting distillates for transport fuels deserve priority attention because of increasing demand (heavy duty road transport, air, marine).
- For advanced biofuels, activities on process optimisation/integration should focus on specific value chains such as those identified by the European Bioenergy Initiative, with ongoing pilot, demo and reference plant projects.
- Value chains leveraging on industrial synergies with existing facilities deserve priority attention as they might offer the best economic and industrial framework to manage the high risk/high cost of deploying promising new technologies, helping the transition from conventional to advanced biofuels.
- New "tools" need to be further evaluated and developed/adapted for EU feedstock applications:
  - Synthetic biology to produce "drop in" biofuels (biofuels with chemical and physical composition fully compatible with current fuel infrastructures)
  - Catalytic and chemical biomass conversion (i.e. catalytic conversion of sugars to furanics)
- Aviation and marine fuels: no specific technical challenges for processing technologies, but mostly (downstream) fine-tuning of processes already developed for road transport fuels.

**Advanced biofuels** are defined either by a wider range of feedstocks (including cellulosic feedstocks from residual/ waste biomass, dedicated energy crops as well as new concepts (e.g. algae, etc) or by enhanced fuel properties of the end product, when compared to current biofuels (ethanol and AME biodiesel), or are chemically closer or identical to fossil fuels, and hence allow the use of current fuel infrastructures (pipe, storage, engines) without technical limitation. Advanced biofuels can be produced via thermochemical or biological process steps or a combination of both.

**Conventional biofuels** include ethanol from starch and sugar crops and biodiesel from vegetable oil, animal fats (FAME, HVO), which are produced from traditional crop options (including food & feed crops) using simple and commercially established processing technologies.

[19] *Synthetic biology is the rational design of the metabolism of a microorganism to produce a desired molecule with high yield, and productivity, using modern biotechnology tools.*

## Main recent evolutions

Biofuels such as ethanol from sugar or starch, or fatty acid methyl ester from vegetable oils, have been produced on an industrial level for years and can, with some confidence, be called "conventional". The ambitious EU 2020 targets, however, are unlikely to be met if relying only on these conventional biofuels. Hence there is a need to develop so-called advanced biofuels, to enlarge the feedstock base and to use the existing feedstocks more efficiently. This course of action is explicitly desired by the EU, and promoted through regulations such as the RED.

While conventional biofuels will still represent a significant share of renewable fuels in 2020, advanced biofuels are needed to reach the 10% target. Corresponding technologies and value chains will have to be developed to a commercial level, and will make use of additional feedstock sources, e.g. lignocellulosic biomass such as agricultural residues. The development of biofuel production through biochemical and thermochemical conversion technologies is crucial. Technological advancement should be used for cost reduction along the whole value chain. In order to comply with the RED GHG reduction level, conversion processes should aim for GHG cuts of more than 60%.

The biomass feedstock situation across the EU is very diverse, both in qualitative and quantitative terms, and different policies exist on promotion of biofuels, bioenergy and other valuable use of land and biomass. This creates differentiated economic values for the same products across the Member States. Because of this, and the fact that corresponding regulations are not yet stable, it is not possible to point directly at priority technologies whose development would ensure that bioenergy 2020 targets can be met.

A toolbox of processing technologies is needed to cope with variable feedstock quantities and qualities and different end uses. Because of the low energy density and high oxygen content of biomass feedstocks (except for lipids), the conversion chains to produce biofuels release significant amount of energy in the process and the overall energy and carbon efficiency tend to remain low compared to fossil alternatives, if the released heat energy cannot be utilised. In this context, evaluation of conversion technologies will also need to consider that most value chains also produce by-products, some of them actually of much higher value than the fuel itself (e.g. chemicals, which is in line with the biorefinery concept). The improvement of gasification systems for the flexible use of different biomass types (including wastes), either independently or combined, makes it possible to work with a broader range of raw materials. Therefore it is necessary to improve the efficiency and versatility of gasification systems for different biomass fuels.

Since the publication of the 2008 SRA/SDD, several pilot and demonstration plants for advanced biofuels have been built and become operational (see examples in Annex 3) – more in North America than in the EU, with the result that the EU's technology leadership in this area is increasingly being challenged[20].

## R&D recommendations

Research on conventional biofuels will primarily aim to strengthen their sustainability with regard to both economic and environmental performance. Environmental issues to be taken into consideration include GHG emissions, energy balances, water balance and management as well as material inputs. Research priorities for advanced biofuels will, of course, target commercialisation, as these technologies are not yet on the market. Solutions need to be found for cost-effectively processing a wide range of sustainable feedstocks on a large scale while ensuring energy and carbon efficiency as well as selectivity towards higher-value products. Compatibility with existing fuel infrastructures at increasing blend rates should be aimed at. The pathways which future R&D will consider comprise gasification as well as pyrolysis and bio-chemical processes. In all cases, it will be necessary to focus on a specific value chain and implement it in pilot, demo and ultimately reference plants. Conversion technologies for transport fuels deserve priority attention because of increasing demand especially from heavy duty road transport as well as air and marine transportation.

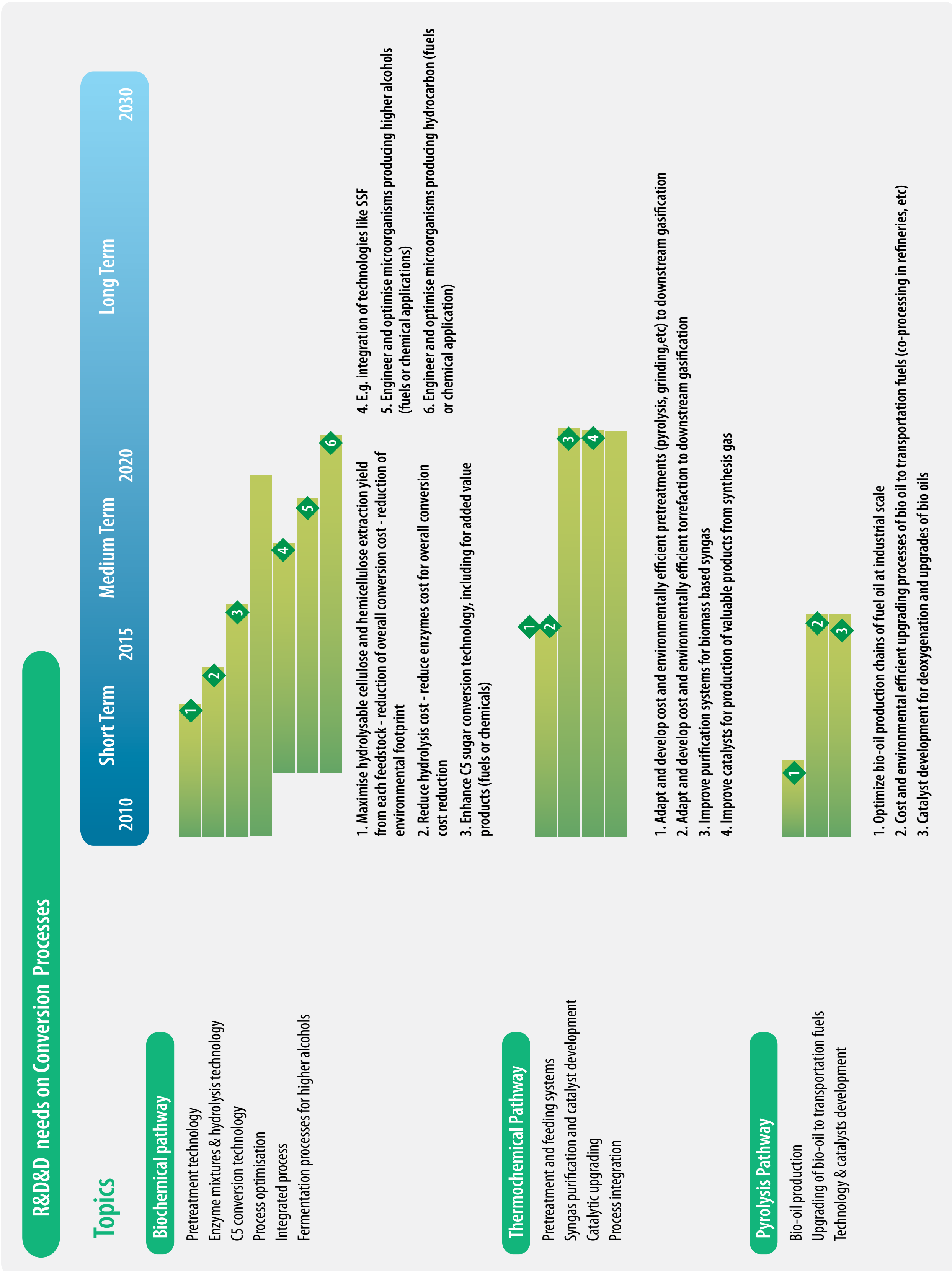
Value chains which make use of synergies with existing facilities offer the best economic and industrial framework to manage the high risk/high cost of deploying promising new technologies, and can thus help the transition from conventional to advanced biofuels. Such value chains deserve priority attention.

A topic which has come up on the biofuels R&D agenda very recently is the application of **synthetic biology**. Synthetic biology can be defined as the rational design of micro-organisms whose metabolism is engineered towards the production of specific high-value molecules. Synthetic biology was first applied in the pharmaceutical area. In the case of biofuels, synthetic biology could be a tool to produce molecules which can directly be blended with fuels ("drop-in"). The advantage of "drop-in" biofuels is that the chemical and physical properties are fully compatible with the current fuel infrastructure. Another important topic is the catalytic and chemical conversion of biomass, e.g. the catalytic conversion of sugars to furanics.

Another possible strategy to improve biochemical pathways is known as "consolidated bioprocessing" (see e.g. Mascoma and Qteros in the USA). This technology aims to simplify the production process by integrating the processing steps of pre-treatment, hydrolysis and fermentation as much as possible in one organism. Alternative strategies such as on-site enzymes production, jointly optimising pre-treatment /hydrolysis/ fermentation etc. are thinkable but need to be tested and assessed.

**Advanced biofuels** will be expected to perform at least as well as, but preferably better than, existing ones from an overall sustainability point of view. Moreover, end users will favour new fuels that are fully compatible with, or chemically identical to, conventional options, to allow for different blend ratios without a need for drastic changes to existing infrastructure. The concept of "drop-in fuels" is of particular interest in cases where fuels corresponding to global standards are crucial, e.g. in aviation. Apart from that, no specific technical challenges for processing technologies were identified in the field of aviation and marine fuels. The focus here is mainly on (downstream) fine-tuning of processes already developed for road transport fuels.

[20] *See , for example, the IEA Bioenergy Task 39 database: http://biofuels.abc-energy.at/demoplants/*




***R&D&D Needs on Conversion Processes***

*The column to the left of the green bars indicates the research topics. Research objectives are indicated by the numbers in the bars and  are described below. The placement of the numbers indicates the estimated time of achievement.*

# 8. Product distribution and use

## Key facts and recommendations

### Main recent evolutions

- Biofuel share of the EU market for road transport fuel is rising, with increasing appetite for distillates to serve markets for transport fuels (road, aviation, marine).
- Higher level of biofuel blends due to increased biofuel targets creates new challenges with regard to specifications/ standards.
- Renewable Energy Directive (RED) and Fuel Quality Directive (FQD) provide incentives for RES across all transport sectors, including aviation and marine, increasing the overall demand for biofuels.
- Development of specific infrastructure for gaseous fuels and liquefied biofuels such as methane/SNG, DME is ongoing in the EU on a local basis for fleets.
- New scenarios for road transport needs have recently been developed (ERTRAC[21]). Biofuels represent one of several solutions, together with increasing energy efficiency, inter-modality, electrification and non-technical measures to encourage changes in consumer choices and behaviour.

### R&D recommendations

- Continuous improvement of distribution and end use system performance, also to implement optimised value chains.
- 2008 R&D&D priorities remain valid, RED 10% target confirms the relevance of tackling the challenges posed by higher blends, e.g. fuel distribution and end use in vehicle.
- Marine, and particularly aviation applications: new issues with regard to fuel specification and fuel/engine (current & future) compatibility.

Requirements concerning fuel distribution systems and end use vehicles have remained stable over the past years and thus have not changed since the 2008 SRA/SDD was published. It is obviously advantageous that alternative fuels be compatible with existing technologies and infrastructures, be it in transport, storage, handling or engines. This is especially important in view of new regulations since 2008 (e.g. the RED target of 10% RES in transport by 2020, but also international developments such as in the USA), which will result in higher blend ratios for biofuels not yet compatible with current specifications.

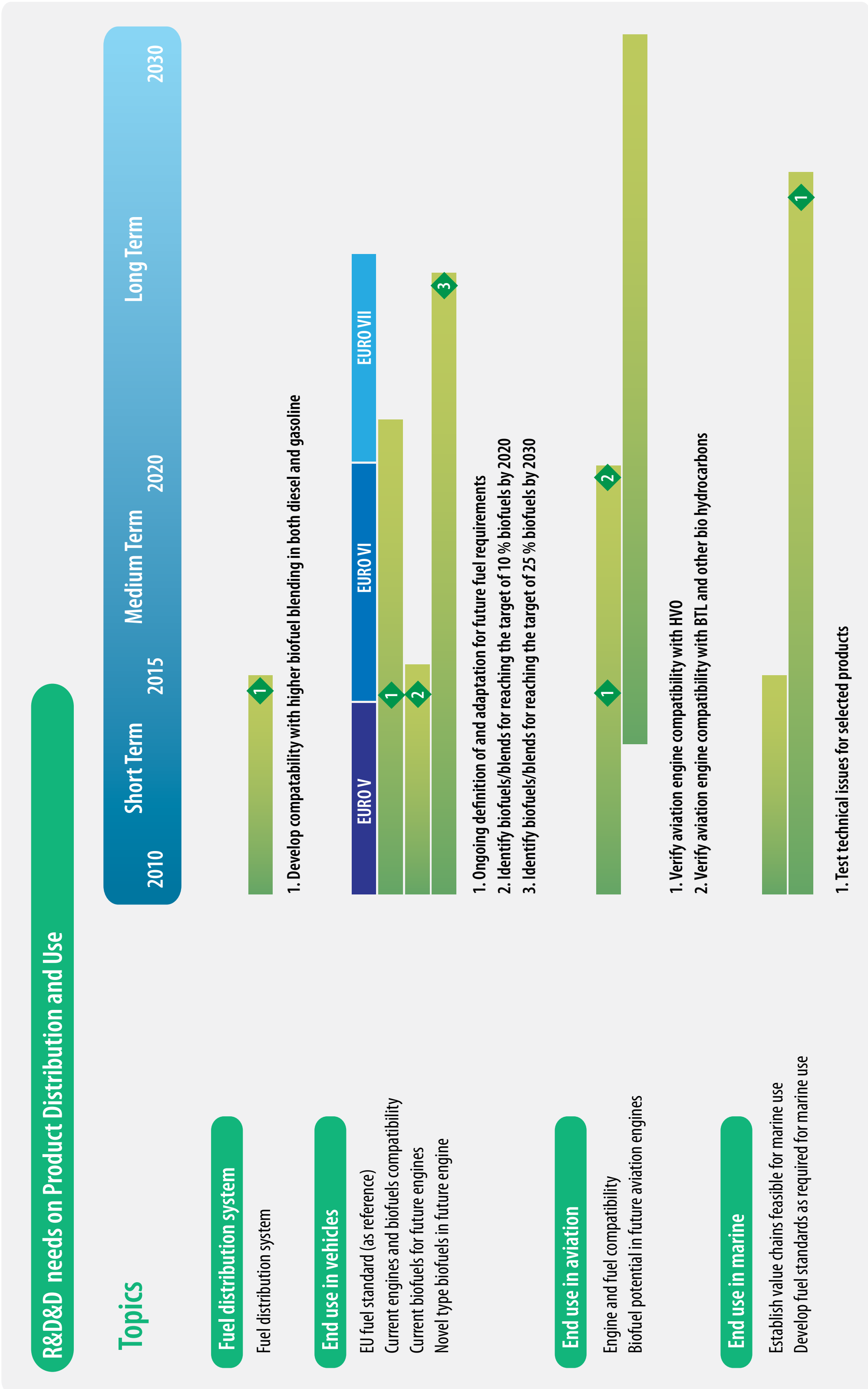
Fuel standards should be adapted to allow increased biofuel shares within existing infrastructures and end-use vehicles. As value chains are optimised, distribution and end use systems must be continuously adapted and public awareness has to be ensured as well.

The RED now applies to all transport sectors, not merely road transport. Aviation and marine transport were taken into consideration due to their high GHG emissions, as well as other environmental concerns, and incentives are now being provided to use RES in these sectors, too. These additional potential consumers pose new challenges for biofuel production, and therefore for research and development: aviation absolutely depends on fuel qualities meeting the same quality requirements worldwide and is also extra sensitive with regard to energy density of fuel. Standardisation is therefore a crucial issue for the sector, as is fuel-engine compatibility. Marine transport, on the other hand, is a low-end fuel market, and thus much more price-sensitive than other transport sectors. It is therefore essential to establish the economic feasibility of fuels to be used in the marine sector.

Upstream of these specification issues, aviation and marine fuels mostly rely on the same feedstocks and industrial processes that apply to road transport fuels. Hence, it is anticipated that biofuel processing technologies already developed for road transport fuels will apply. The "finishing" processing to fine-tune specific products should preferably be dealt with using currently available refining technologies.

While various gaseous biofuels for land transport are currently being developed throughout Europe (methane/SNG, DME), these require a specific distribution infrastructure and are therefore best suited to metropolitan areas and fleets for local public transport. Such local fleets (public or private) may also be fuelled by electricity or pure biofuels, while liquid biofuels will likely remain the renewable option of choice for long-distance freight transport and aviation.

[21] *ERTRAC, European Road Transport Research Advisory Council (2009): Road transport Scenario 2030 + "Road to Implementation"*




***R&D&D Needs on Product Distribution and End Use***

*The column to the left of the green bars indicates the research topics. Research objectives are indicated by the numbers in the bars and are described below. The placement of the numbers indicates the estimated time of achievement.*

# 9. European Industrial Bioenergy Initiative[22]

## Key messages

- Based on the SET Plan proposal in 2007, 6 Industrial Initiatives are being developed, including one on bioenergy. Over the last 2 years, EBTP has actively contributed to shaping the European Industrial Bioenergy Initiative (EIBI)
- The purpose of EIBI is to accelerate the commercial deployment of advanced technologies to boost the contribution of sustainable bioenergy to EU 2020 Climate and Energy targets.
- EIBI focuses on innovative bioenergy value chains that are not yet commercially available and that could be deployed at large scale.
- The key objective of EIBI is to enable commercial availability of advanced bioenergy at large scale by 2020, aiming at production costs[23] that are competitive with fossil fuels, and enabling advanced biofuels[24] to cover up to 4% of EU transportation energy needs by 2020, in line with the sustainability criteria of the EU.
- EIBI also intends to strengthen the EU's global technology leadership in renewable transport fuels for diesel and jet engines[25], serving the fastest growing area of transport fuels in the world.
- Provided that supportive framework is available to manage high cost and risk of industrial deployment, a set of innovative industrial bioenergy value chains could be successfully deployed in Europe.
- Seven innovative bioenergy value chains have been identified, which could bring significant contributions to the EU's ambitious objectives, in addition to existing bioenergy value chains,.
- The focus of EIBI should be on those value chains which could bring large volume contributions, and which are too costly to be developed and funded at national level.
- Demonstration of the sustainable performance of these technologies over the complete value chain is critical for securing financing for commercial large scale deployment and achieving social awareness.
- The selection and funding of demonstration and/or reference plants projects will constitute the core activity of EIBI. With an estimated budget of 8 billion € over 10 years, 15 to 20 demonstration and/or reference plants could be funded.
- Governance, funding and definition of eligibility and selection criteria for projects are being currently actively discussed with the European Commission and the Member States.
- The official launch of the EIBI is expected in November 2010.

## SET Plan

In November 2007, the European Commission presented the European Strategic Energy Technology Plan, SET Plan, COM(2007)723, which was adopted by the Energy Council of Ministers in February 2008 as a basis for the energy technology policy for Europe, aiming at the wide-scale application of low carbon technologies.

The SET Plan calls for strategic planning and new governance to align technology development with energy policy goals. Among the tools envisaged for the implementation of the SET-Plan, European Industrial Initiatives are expected to play a critical role.

The key features of an European Industrial Initiative as presented in the SET-Plan are as follows:

- The initiative should not be realistically feasible at national level and should clearly leverage on European scale capability for additional resources and added value.
- It should be industry led, pool public and private financing and share risk via public-private partnership.
- It should be based on the definition and achievement of clear targets with quantified objectives.
- It should boost research and innovation in order to deliver results beyond business as usual.

The European Industrial Bioenergy Initiative (EIBI) is one of the 6 priority European Industrial Initiatives proposed initially. The first European Industrial Initiatives are launched in June 2010, EIBI is expected to follow in November 2010.

[22] *Development of the EIBI is an ongoing process, and information presented in this SRA update reflects the status of the initiative as at 26 June 2010.*

[23] *Production costs of biofuels depend heavily on investment intensity, on the degree of utilisation of primary energy and the feedstock price, with significant differences across geographic areas and specific feedstock types.*

[24] *Sustainable biofuels with a broader raw material base and/or better end product properties than those biofuels currently on the market.*

[25] *This comprises fuels for the transport needs of diesel-fuelled cars, trucks & buses, off-road vehicles, ships and airplanes*

## Bioenergy in the EU 2020 Climate & Energy Package

For all applications and especially the transport sector, bioenergy will play a key role in reaching the EU 2020 climate and energy targets, contributing up to 14% of the EU energy mix and up to 10% of energy demand in transport. The challenges are considerable for Member States to meet the 2020 targets under current business and regulatory conditions. Currently, commercially deployed feedstocks and conversion technologies already provide a significant contribution, but will not be sufficient to reach these targets.

Significant R&D and pilot activities have been ongoing for the past decade in EU Member States to enlarge the feedstock base by additional sustainable and competitive sources and to develop processing technologies able to deal with a wider feedstock base, enhance feedstock conversion into valuable energy and co-products, minimise overall energy consumption and meet EU sustainability criteria. Processing technologies cannot be developed at industrial scale on a stand-alone basis, but only as part of commercial "value chains", i.e. integrated process schemes, from feedstock to end products. Because of the magnitude of the investment needed, they are unlikely to be met in a context of uncertainty on the availability of required feedstock as well as on the economic and political frameworks.

The diversity of bioenergy value chains of potential relevance, the multiple issues impacting their development, and the complexity and high cost of the technologies needed to be deployed, calls for a EU-wide approach, with adequate governance and funding to operate as public/private partnerships. EIBI is expected to be the enabling tool for such challenges.

## EIBI

The purpose of EIBI is to boost the contribution of sustainable bioenergy to EU 2020 climate and energy objectives, with a focused approach leveraging on public-private partnerships to manage the risks and share the financing.

The focus is on innovative bioenergy value chains[26] that are not yet commercially available (thus excluding current biofuels, heat & power, biogas, etc), could be deployed at large scale (large single units or larger number of smaller units) and that comply with the sustainability requirements of the RES Directive (2009/28/EC).

The specific objectives of the EIBI are to:

1. to enable commercial availability of advanced bioenergy at large scale by 2020, aiming at production costs[27] competitive with fossil fuels in the prevailing economic and regulatory market conditions, and advanced biofuels[28] covering up to 4% of EU transportation energy needs by 2020,
2. to strengthen EU world technology leadership in renewable transport fuels for diesel and jet engines[29], serving the fastest growing area of transport fuels in the world.

To achieve these objectives, the core activities of EIBI will be the selection and funding of demonstration projects and/or reference plants for innovative bioenergy value chains with large market potential. Seven innovative bioenergy value chains have been identified, which could bring significant contributions to EU ambitious objectives, in addition to existing bioenergy value chains (see box below). **This list is not exhaustive.**

9

### 7 "generic" value chains

**A) Conversion paths based on thermochemical processes:**

(1) Synthetic fuels / hydrocarbons from biomass via gasification (main markets: renewable transportation fuels for jet and diesel engines)

(2) Bio-methane and other gaseous fuels from biomass via gasification (substituting natural gas and other gaseous fuels)

(3) High efficiency power generation via gasification of biomass (main markets: electricity for large scale plants, CHP for smaller plants (below 20 MWel)

(4) Bioenergy carriers from biomass via other thermo-chemical processes, e.g. pyrolysis, torrefaction etc (main markets: fuels for heating, power generation or intermediates for further upgrading into transport fuels).

**B) Conversion paths based on biological and chemical processes:**

(5) Ethanol and higher alcohols from sugars containing biomass (main market: renewable transportation fuels as gasoline components, E85)

(6) Renewable hydrocarbons from sugars containing biomass via biological and/or chemical process (main markets: renewable transportation fuels for jet and diesel engines)

(7) Production of bioenergy carriers from $CO_2$ & sunlight through micro-organism based production (algae, bacteria etc.) and further upgrading into transportation fuels and valuable bio-products (main market renewable transport fuels for jet and diesel engines)

26 *Value Chain: specific combination of feedstock, processing technologies and marketable end products, corresponding to energy driven biorefineries.*

27 *Production cost of biofuels depends heavily on investment intensity, on the degree of utilisation of primary energy and on feedstock price, with significant differences across geographic areas and specific feedstock types.*

28 *Sustainable biofuels with a broader raw material base and/or better end product properties than the biofuels currently on the market*

29 *This comprises fuels for the transport needs of diesel fuelled cars, trucks & buses, off road vehicles, ships and airplanes*

Within each of the 7 "generic" value chains, different paths based on different fossil feedstocks (including fossil co-processing), technologies and/or industries are possible. Combinations of thermo-chemical and biological processes are also possible. They all correspond to different types of energy-driven biorefineries.

The critical technologies for these value chains are at different level of maturity. Relevant scientific and technological know-how to develop these value chains is available within industry, universities and research institutions in the EU.

Demonstration of the sustainable performance of these technologies over the complete value chain is critical for securing financing for commercial large scale deployment and gaining social awareness. The earliest industry actors are ready to move to a demonstration and/or commercial reference plant, provided a relevant framework ensures sharing risks and financing via public/private partnership. Others will be ready in the coming years, allowing to spread EIBI project selection activity between 2010 and 2015.

The preliminary estimated budget to build and operate 1 to 3 Demonstration and/or Reference Plants within each of the 7 "generic" value chains is 6-8 billion € over 10 years. These Demonstration projects and/or Reference Plants will be industry-led.

Key actors within each project should come from at least three Member States.

The EIBI initiative will also include important R&D challenges for the existing public research capacities in Europe. Applied R&D will play a key role in directly supporting selected demonstration and reference projects; strategic R&D will be needed for the long term development of the whole sector, in cooperation with relevant initiatives such as the European Energy Research Alliance (EERA).

To ensure clear focus and strong partnership of critical actors within each EIBI project, several topics of relevance to overall bioenergy development will not be in the direct scope of EIBI. Such topics are:

- Demonstration projects exclusively focused on improving yields & quality characteristics of biofeedstocks (existing and new)
- Small niche & locally specific bioenergy value chains
- Biorefineries that are not focused on bioenergy
- Demonstration of new logistics end use solutions which are not bio specific

EIBI will, however, ensure linkage and synergies with relevant initiatives dealing with these topics.

Sustainable and reliable supply of feedstocks will be a critical success factor for the long-term perspective of biomass-based technologies on a large scale. This relates to efforts in improving productivity in these sectors and in developing reliable supply chains that open up the feedstock potentials. Certification issues and prevention of excessive disturbances in agricultural and forest commodity markets are also crucial. These challenges are not specific to bioenergy use of biomass and should be addressed in a coherent effort shared with the relevant stakeholders and initiatives.

## EIBI Implementation

Based on the objectives, scope and core activities of the (EIBI)[30] proposal presented, discussed and approved at the Stockholm SET Plan conference session on the bioenergy industrial initiative[31] and the outcome of the SET Plan Steering Group meeting on the next steps for European Industrial Initiatives[32], EBTP is pursuing active dialogue with the European Commission and relevant stakeholders to further elaborate the EIBI.

The next step is the definition of the implementation plan, together with EU and Member States representatives willing to take part in the governance and financing of this Public Private Initiative.

The EIBI Implementation Plan should provide a framework to select, validate and implement risky and cost-intensive projects which enable synergies between key industry actors and EU Member States. The framework needs be flexible enough to adjust to the different risk profiles and characteristics of each value chain.

An "EIBI Team" is being formed, including representatives of the European Commission, Member States , EBTP and other stakeholders. It will be supported by the EIBI Project Selection Criteria Task Force. Within the Biofuels TP, a horizontal Working Group will co-ordinate all EIBI related activities.

The first four Industrial Initiatives of the SET-Plan were launched in June 2010 under the Spanish EU presidency. The envisaged launch date for EIBI is November 15th/16th 2010 at the next SET Plan Conference under the Belgian Council Presidency.

[30] *"Boosting the contribution of bioenergy to the EU Climate & Energy ambitions", discussion document prepared by EBTP, dated 27 July 2009*

[31] *Report of the outcome of the Bioenergy parallel session of Oct 2009 SET Plan conference*

[32] *SET Plan secretariat note dated 14 Dec 2009*

# Annex 1. Biofuels-related R&D&D topics covered by EU (under FP6&/FP7), Member State and international funding

## Key messages and recommendations

- EBTP Secretariat has aimed to identify recent biofuels related R&D activity at EU level.
- Exact overview difficult to obtain, due to interdisciplinarity of topic and multitude of funding organisations and programmes, at least at national level.
- Increasing funding of EC and Member State funding for research, technology development and demonstration.
- JRC estimate of biofuels R&D in the EU for 2007 347 M€ (public and private), more than 85% of public funding from Members States.
- EC funding moves from current to advanced biofuels and biorefineries.
- Increasing R&D activities around the world with US, Canada and Brazil as main countries.
- Increasing focus on pilot/demonstration activities of advanced biofuel/biorefinery technologies in US and Canada with large programmes (several 100 M€).
- Better database of ongoing activities is required.

The Secretariat of the EBTP has attempted to identify and collate recent EU-level R&D activities in the area of biofuels. It was noted that a complete overview is very difficult to achieve due to the scientific and policy interdisciplinarity of the topic. The multitude of funding organisations and programmes on Member State level further complicates information exchange.

Biofuel-relevant projects are funded within several areas of the FP6 and FP7, such as Energy, KBBE and Environment. There are specific biofuel calls as well as projects on generic topics (such as plant breeding, environmental impacts of agriculture or transport) which produce results relevant to biofuel production and use. Similarly, biorefinery projects cover a whole range of products but may include biofuels. Of course, such joint facilities make specific calculations, e.g. for biofuel production costs, difficult or impossible. Moreover, statistics may or may not include demonstration activities.

Overall, it was emphasised that databases of ongoing activities need to be improved.

It could, however, be ascertained that funding for research, technology development and demonstration increased both at EU and national level. The JRC estimate of 2007 put R&D funding (public and private combined) of biofuels at 347 M€, over 85% of which came from Member State public budgets. [33]

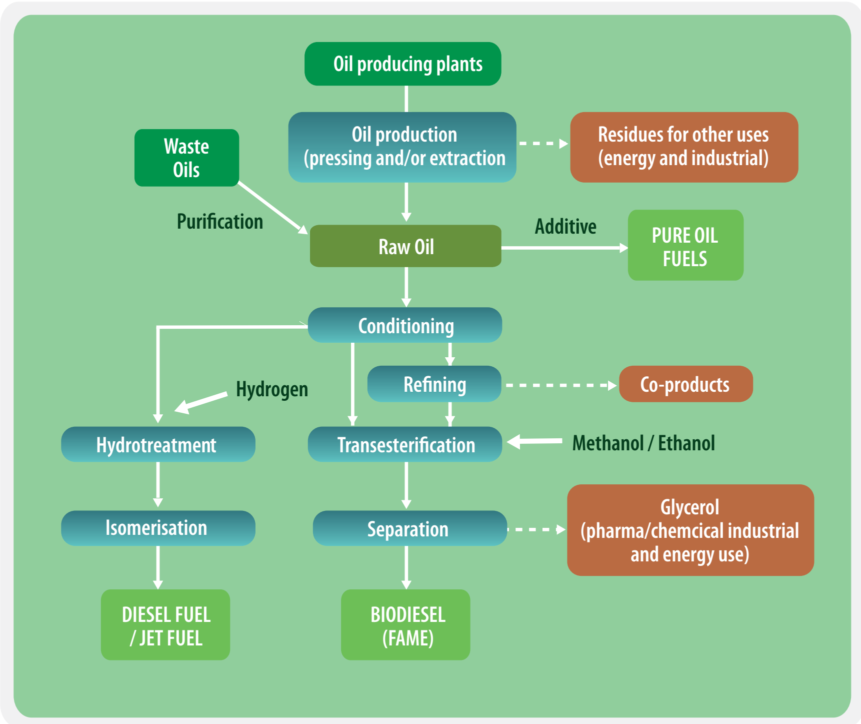
This development is mirrored by global activities, with R&D activities in the main countries (Brazil, Canada, USA) also on the rise.

Especially in Canada and in the USA, the focus seems to be shifting towards piloting and demonstration of advanced biofuel and biorefining technologies, with large-scale (several 100 M€) programmes to support such projects. Implementation of these projects is complex with the result that sometimes not all programme funds are used. Also funding by the EC is moving from conventional to advanced biofuels and biorefineries, too.

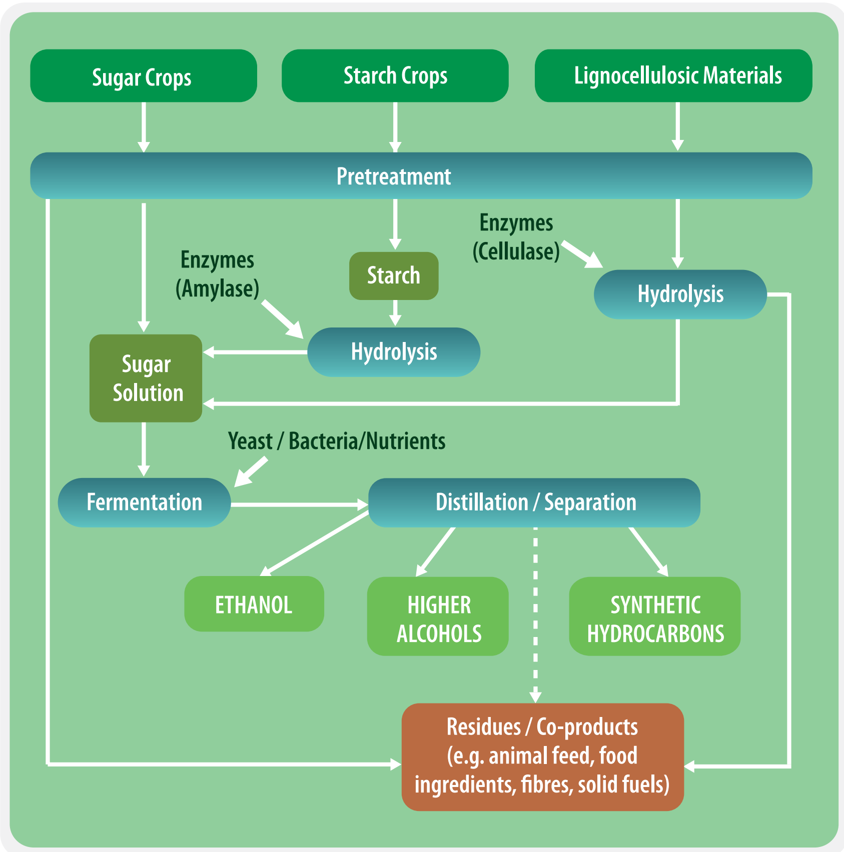
In conclusion, a number of the R&D priorities identified in the 2008 SRA were addressed by subsequent projects under the Framework Programme (FP6 or FP7). As many FP7 projects started only recently, it is too early to draw any conclusions as to their impact or to possible gaps. However, activities which aim to increase biomass production potentials seem to be limited so far.

[33] *JRC, European Commission Joint Research Centre (2009): R&D Investment in the Priority Technologies of the European Strategic Energy Technology Plan*

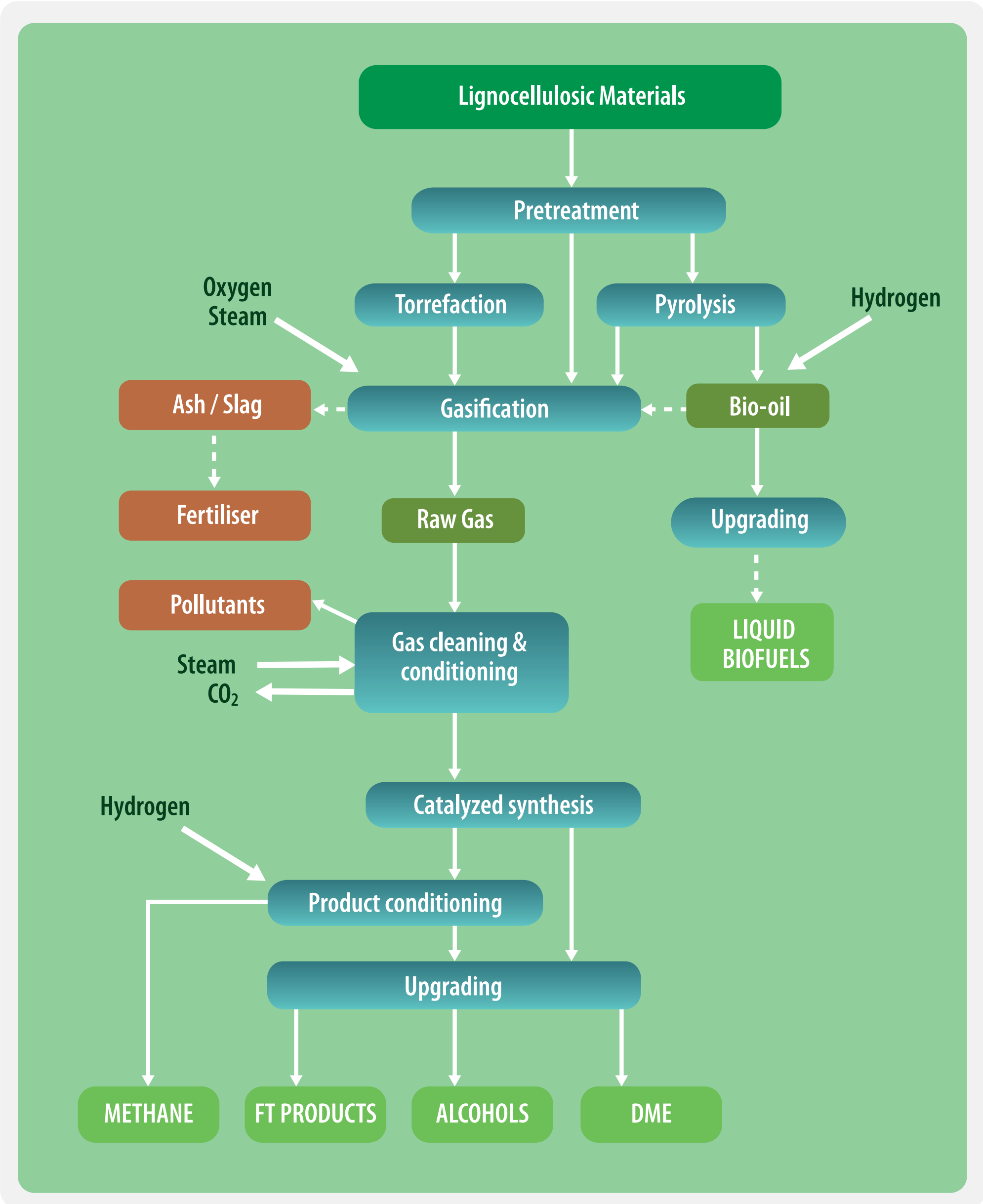
## Annex 2. Overview of Conversion Processes




***Technology Box A:*** *Oil and fat based balue chains*




***Technology Box B:*** *Biochemical value chains*




***Technology Box C:*** *Thermochemical value chains*

## Annex 3. Examples of European demonstration plants for advanced biofuels

*(list is not exhaustive)*

| Name of Project / Plant | Country | End-Products | Feedstock | Level of maturity | More information |
|---|---|---|---|---|---|
| **BornBioFuel** | Denmark | Ethanol | Ligno-cellulosic material | Planning | www.biogasol.com/Projects-177.aspx |
| **ECN/HVC BioSNG Project** | Netherlands | BioSNG | Ligno-cellulosic material | Planning | www.biosng.com/ |
| **PRO.E.SA** | Italy | Ethanol | Ligno-cellulosic material | Under construction | Groupo M&G |
| **CHOREN Beta Plant** | Germany | BTL Synthetic Fuel | Waste wood, forest residues, SRC, straw | Final commissioning | www.choren.com |
| **Abengoa** | Spain | Ethanol | Agricultural residues (esp. wheat straw) | Running | www.abengoabioenergy.com |
| **Kalundborg Ethanol Demo plant** | Denmark | Ethanol, C5, molasses, lignin biofuel pellets | Wheat Straw | Running | http://www.inbicon.com/ |
| **BioMCN** | The Netherlands | Methanol | Crude glycerin | Running | http://www.biomcn.eu/ |

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## Annex 5. Abbreviations

| | |
|---|---|
| ABE | Acetone - Butanol-Ethanol |
| BECOTEPS | Bio-Economy Technology Platform |
| BTL | Biomass-to-Liquid |
| CDM | Clean Development Mechanism |
| CEN | Comité Européen de Normalisation |
| $CH_4$ | Methane |
| CHP | Combined heat and power |
| CI | Compression ignition engine |
| $CO_2$ | Carbon dioxide |
| DME | Dimethyl eether |
| EBTP | European Biofuels Technology Platform |
| EIBI | European Industrial Bioenergy Initiative |
| EJ | Exajoule, scale factor: $1.0^{E+18}$ |
| ERTRAC | European Road Transport Research Advisory Council |
| FTP | Forest-based SectorTechnology Platform |
| FP | Framework Programme |
| FQD | Fuel Quality Directive |
| GHG | Green House Gas(es) |
| GJ | Giga-Joule |
| GMO | Genetically Modified Organism |
| ha | Hectare |
| HVO | Hydrogenated vegetable oil |
| IEA | International Energy Agency |
| ISO | International Organization for Standardization |
| JRC | European Commission Joint Research Centre |
| KBBE | Knowledge-Based Bio-Economy |
| LCA | Life Cycle Analysis |
| LPG | Liquefied petroleum gas |
| MJ | Mega-Joule |
| Mtoe | Million tonnes of oil equivalent |
| $N_2$ | Nitrogen |
| NGO | Non-governmental organisation |
| P | Phosphorus |
| ppm | Parts-per-million |
| R&D&D | Research, Development and Deployment |
| RDF | Refuse Derived Fuel |
| RED | Renewable Energy Directive (EU) |
| RES | Renewable Energy Sources |
| RFS2 | Renewable Fuels Standard Program (US) |
| SET Plan | Strategic Energy Technology Plan |
| SI | Spark ignition engines |
| SNG | Synthetic natural gas |
| SRA/SDD | Strategic Research Agenda/Strategic Deployment Document |
| SSF | Simultaneous Saccharification and Fermentation |
| StarColibri | Strategic Targets for 2020 Collaboration Initiative on Biorefineries |
| Suschem | European Technology Platform for sustainable Chemistry |
| TP | Technology Platform |
| ZEP | Zero Emissions Platform |