ETIP Bioenergy

European Technology and Innovation Platform

STRATEGIC RESEARCH AND INNOVATION AGENDA 2018

cost-competitive

innovative

world-class

bioenergy and biofuel value chains

European Technology and Innovation Platform Bioenergy

cost-competitive, innovative world-class bioenergy and biofuels value chains

The European Technology and Innovation Platform Bioenergy (ETIP Bioenergy) was launched in 2016 and combines the efforts of the European Biofuels Technology Platform (EBTP), which started in 2006, and the European Industrial Initiative Bioenergy (EIBI), which started in 2010. The mission of ETIP Bioenergy is to contribute to the development of cost-competitive, innovative world-class bioenergy and biofuels value chains, to the creation and strengthening of a healthy European bioenergy industry and to accelerate the sustainable deployment of bioenergy in the European Union through a process of guidance, prioritisation and promotion of research, technology development and demonstration.

It brings together the knowledge and expertise of stakeholders active in the bioenergy and 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 bioenergy and biofuels R&D&D. Platform activities are carried out through currently four working groups (Biomass availability and supply, Conversion, End use and product distribution, Policy and sustainability) and Advisory Board comprises technical experts from Member States.

EBTP and ETIP Bioenergy have published Strategic Research (and Innovation) Agendas in 2008, 2010 and 2016. In light of the broadened scope of ETIP Bioenergy, new legislation and an ongoing debate on the availability and sustainability of feedstocks, as well as the acceleration of novel feedstocks, advanced conversion technologies, and emerging markets (e.g. aviation, shipping) this Strategic Research and Innovation Agenda Update has been produced by the ETIP Bioenergy Steering Committee, Working Groups and the ETIP Bioenergy SABS project partners.
The document complements recent or upcoming Strategic Research and Innovation Agendas (SRIA) of other organisations on the same or related topics, such as the Biomass Panel of the European Energy Research Alliance (EERA).

For more information on the
European Technology and Innovation Platform Bioenergy please visit
www.etipbioenergy.eu

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LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
BBI	Bio-based Industries
BtL	Biomass to Liquid
CO_2	Carbon dioxide
CNG	Compressed Natural Gas
CAPEX	Capital Expenditure
DDF	Diesel Dual Fuel
DME	Dimethyl ether
EBTP	European Biofuels Technology Platform
EC	European Commission
EIBI	European Industrial Bioenergy Initiative
ERTRAC	European Road Transport Research Advisory Council
ETBE	Ethyl Tertiary Butyl Ether
EU	European Union
EV	Electric Vehicles
FAME	Fatty Acid Methyl Ester
FFV	Flex-Fuel Vehicles
FQD	Fuel Quality Directive
FTE	Full Time Equivalent
GHG	Green House Gas(es)
HEFA	Hydroprocessed Esters and Fatty Acids
HD	Heavy Duty
HDV	Heavy Duty Vehicle
HVO	Hydrotreated Vegetable Oil
ICE	Internal Combustion Engine
IEA	International Energy Agency
ILUC	Indirect Land Use Changes
IMO	International Maritime Organization
ISO	International Organization for Standardization
Ktoe	Kilo Tonnes of Oil Equivalent
LNG	Liquefied Natural Gas
LCA	Life Cycle Analysis
MS	Member States
Mtoe	Million Tonnes of Oil Equivalent
NGO	Non-Governmental Organisation
OPEX	Operational Expenditure
Ptx	Power to X
R&D	Research and Development
R&D&D	Research, Development and Deployment
RED	Renewable Energy Directive
RES	Renewable Energy Source
SET-Plan	Strategic Energy Technology- Plan
SDD	Strategy Deployment Document
SRA	Strategic Research Agenda
SRIA	Strategic Research Innovation Agenda
SPK	synthetic paraffinic Kerosene
TRL	Technology Readiness Level
TTW	Tank-to-Wheel
UCO	Used Cooking Oil
WTT	Well-to-Tank
WTO	World Trade Organisation

1 EXECUTIVE SUMMARY

The aim of this update is to present most significant recent developments of relevance to bioenergy and biofuels and to highlight corresponding R&D&D priorities.

FACTS

- Since 2009, the European biofuels policy has been dominated by the framework given by the Fuel Quality Directive (FQD) and the Renewable Energy Directive (RED), setting a target of 10% for renewables in transport fuels by 2020.
- The following years were dominated by a debate about indirect land use effects caused by biomass used for biofuels. The EC Communication on the 2030 Climate and Energy Goals in January 2014, which did not foresee a specific target for biofuels, added to the uncertainty for the sector and, together with low oil prices, reduced investment interest.
- In April 2015, the so called "ILUC Directive" entered into force, setting limits how to meet the target of 10% for renewables in transport fuels by 2020. This related to food crop based biofuels in particular. In 2016, a renewables share of 7.1% in transport was reached and the expectations are that the 10% target for 2020 will be fulfilled.
- In November 2016, the European Commission published a proposal for a RED II directive for the period up to 2030.
- In June 2018, following an intense debate and trilogue negotiations, the RED II was agreed upon between Council, Parliament and Commission. The RED II includes a renewable energy target for transport of 14% by 2030, as well as a subtarget for advanced biofuels of 3.5%.
- Several industrial units for advanced biofuels have been built and started up in 2014-15 much more in America than in the EU, whose technology leadership on this topic is increasingly being challenged.
- In the transport sector, the "dieselgate" 2015 reduced the diesel demand for passenger cars. Other alternative fuels such as CNG, LNG, electrofuels and electric vehicles offer new choices.
- For electricity, wind and PV have increased their market share; fluctuating supply gives new challenges to the energy system.
- In June 2018, the Strategic Energy Technology Plan (SET-Plan) Steering Group approved an Implementation Plan for Action 8 Renewable Fuels and Bioenergy with research and innovation actions for the next decade.

OBSERVATIONS AND RECOMMENDATIONS

The fundamentals for biofuels have not changed between 2016 and 2018. As highlighted in the 2016 SRIA, the winning options will be the pathways (combination of feedstock, conversion and end products) best addressing combined strategic and sustainability targets: environmental performances (greenhouse gas reduction, biodiversity, water, and local emissions), security and diversification of energy supply, economic competitiveness and public awareness.
With the RED II political compromise from June 2018, currently commercially deployed feedstocks and conversion technologies have a significantly reduced contribution to the EU 2030 targets. It is necessary to enlarge the feedstock basis into non-food resources and enhance conversion efficiency.

The broad recommendations below were at the core of the last SRA/SDD findings and remain fully valid:

- Ensure a coherent national implementation of the EU biofuel legislation.
- Relevant, transparent and science-based data and tools for practical implementation of sustainability requirements in the legislation and market place should be further developed.
- Support resource efficient supply following a system approach (including legal and financial mechanisms and measures).
- The key priorities for commercial biofuel technologies are to improve environmental (GHG, energy balance, water, inputs…) and economic performance and bring flexibility as integrated biorefinery.
- Conversion technologies targeting fuels for heavy duty road, air, and marine transport deserve priority attention because of lack of low fossil carbon alternatives and their increasing demand
- Work to ensure a fair appreciation of CO_2 emissions (well-to-wheel approach) such that vehicles running on partly or fully on renewable fuels and electric vehicles are treated using equal criteria.
- The SET-Plan Action 8 Implementation Plan with suggested activities worth more than €100bn needs to be executed by stakeholders, Member States and EU.

2 INTRODUCTION AND STATE OF THE ART

The sector of biofuels and bioenergy has seen only limited fundamental changes between 2016 and 2018. The debate on climate change continues; prices of fossil energy carriers fluctuated but stayed low all in all, and uncertainty in Europe about the policy framework for biofuels and bioenergy was however solved in June 2018.

With the move from the European Biofuels Technology Platform (EBTP) to the European Technology and Innovation Platform Bioenergy (ETIP Bioenergy) in 2016, the scope of the platform was broadened. It covers the seven EIBI thermochemical and biochemical value chains described in Annex 1 and Annex 2. The classical heating and cooling sector continues to be represented in the Renewable Heating and Cooling Technology Platform (ETIP RHC).

Biofuels continue to represent the lion share of the activities of ETIP Bioenergy. Renewable fuels have been added to the scope recently, but are not covered by this SRIA.

The transport sector is a very complex sector, which is characterised by the movement of passenger and freight via road transport (LDH, HDV) rail, shipping and aviation. As a result the transport sector represents the second largest energy end use sector.

In Europe the total energy consumption of transport accounted for 359 Mtoe (Million Tonnes of Oil Equivalent) in 2015, whereby the gross inland energy consumption in the EU-28 accounted for 1627 Mtoe. The final end use of energy is split into three dominant categories, the transport sector with 33.1%, the households with 25.4% and the industry with 25.3%[1]. With the largest share of the final end use of energy, the transport sector contributes 25.8% of the total GHG gas emission of the EU- 28 (in 2015). In 2016 renewable energy represented 17% of energy consumed in the EU, on a path to the 2020 target of 20%. The share of energy used in transport activities from renewable sources almost tripled in 10 years to reach 7.1% in 2016 (Figure 1).

Bioenergy accounts for two thirds of the renewable primary energy supply in EU-28. Nearly 14.2 Mtoe of biofuels were consumed in EU 28 in 2015. In 2016 only a slight increase of 1.3% was listed which implies a total biofuel consumption of 14.4 Mtoe. This adds up from a total consumption of 80.6% biodiesel which corresponds to 11,603 Ktoe, a total consumption of 18.4% of bio-ethanol which corresponds to 2.646 Ktoe and a total consumption of 1% for biogas, which correlates to 138 Ktoe.[4] Within this figure the in relative terms small consumption

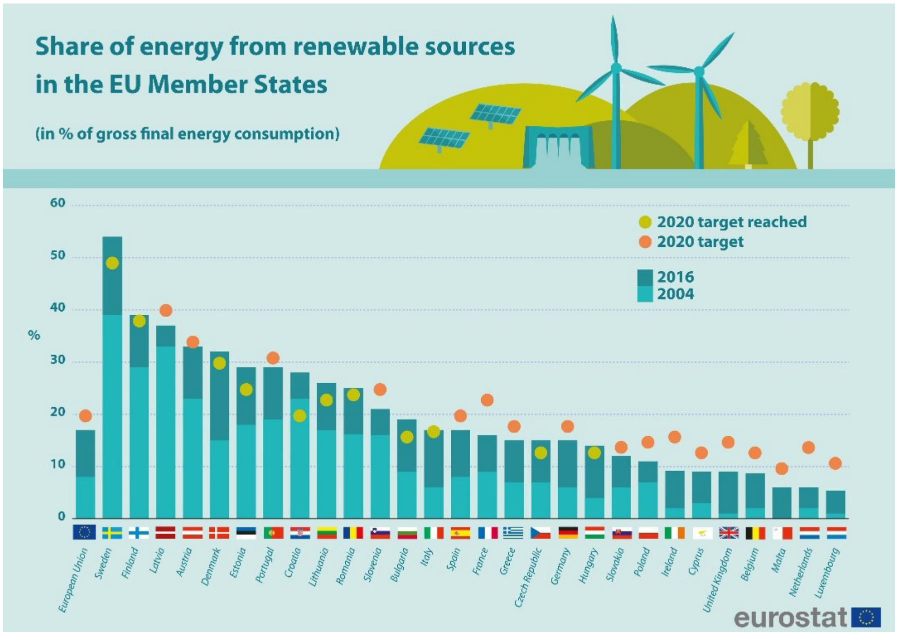


Figure 1: Share of energy from renewable sources 2004-2016 (eurostat) [3]

1 http://ec.europa.eu/eurostat/statistics-explained/index.php/Consumption_of_energy

2 https://www.eea.europa.eu/data-and-maps/indicators/transport-emissions-of-greenhouse-gases/transport-emissions-of-greenhouse-gases-10

3 http://ec.europa.eu/eurostat/statistics-explained/index.php/Renewable_energy_statistics

4 BIOFUELS BAROMETER – EUROBSERV'ER – JULY 2017 https://www.eurobserv-er.org/biofuels-barometer-2017/

of pure vegetable oil used as fuel is already included in the total consumption of biodiesel. The reason for the large share for biodiesel lies with the size of the diesel fleet within the EU, both for light and heavy duty applications. The calculation for bio-ethanol refers to bio-ethanol already blended in petrol (E10) or the bio-ethanol that was already converted beforehand into Ethyl-tert-butyl ether. EU share of global bio-ethanol consumption is still outweighed by countries like Canada, China and the USA[4]. In 2016, approximately 13.3 Mtoe, i.e. 92.5% of EU biofuel consumption, have been certified as sustainable according to the criteria set down in the European Renewable Energy Directive. The forecast for 2018 shows a total of 5.2% biofuels blending with fossil fuels, 3.6% for bioethanol, 5.8% for biodiesel and HVO, a blending of conventional biofuels which are food based of 4.1% and for advanced biofuels which are non-food based are estimated at 1.2% (whereby 1% is produced from waste fats and oils and only 0.2% is produced from agricultural and forestry by-products)[5].

Whilst the energy share of biofuels in transport energy 2016 amounts to 7.1%, double counting rules under the RED leads to the fact that the 2020 target of 10% renewable fuels will probably be met. Under the new RED II biofuels together with RE power are expected to meet the EU 2030 target of 14% renewable energies in the transport sector, as part of an overall renewable energy target of 32%. The advanced biofuels commercialization within recent years has not been as successful as envisaged and at the current state **advanced biofuels have to strengthen their position as one of the key elements in decarbonizing transport for 2030 and beyond, next to options such as electrification, and further energy efficiency improvements.** The transport sector increases its specific efficiency, but still there is an increasing energy demand. Between 2000 and 2016 the global energy demand in the transport sector increased by 39%. The rising freight movement and the overall rising transport demand in emerging and developing countries are the most important driving factors[6].

In Europe the rapid growth phase of biofuels consumption from 2002 till 2010 was terminated with a production decrease in 2011 by 10% (compared to 2010) but recovered with an annual growth rate of about ~10% between 2012 and 2013. Figure 2 shows the European conventional and advanced biofuels as percentage of total fuel use for transport between 2006 - 2018. The decreasing on the demand side, between 2012-2014 was characterized by the discussion about the Revision to the Fuel Quality Directive (FQD) and Renewable Energy Directive (RED) to address ILUC (indirect Land Use Change).

The future situation of biofuels at European level was unclear and investment in the industry deterred hindering the commercialization of these technologies. The so called "ILUC Directive" from September 2015 limits the way Member States can meet the target of 10% for renewables in transport fuels by 2020, but biofuels from food crops were capped at 7%. Member States had to transpose the law into national legislation by September 2017. The reference value for a sub-target for advanced biofuels is 0.5% by 2020 and only advanced biofuels made from feedstocks listed in Annex IX A[7] of the Directive are eligible. MS have to provide a grounded reason for establishing a lower sub-target.

[5] USDA Foreign Agricultural Service . EU Biofuels Annual 2018 . s.l. : The Hague, 2018. GAIN Report Number:NL8027

[6] REN 21- Renewable Energy Policy Network for the 21st Century . RENEWABLES 2018- Global Status Report. 2018. ISBN 978-3-9818911-3-3.

[7] ILUC Directive ANNEX IX Part A: (a) Algae if cultivated on land in ponds or photobioreactors. (b) Biomass fraction of mixed municipal waste, but not separated household waste subject to recycling targets under point (a) of Article 11(2) of Directive 2008/98/EC. (c) Bio-waste as defined in Article 3(4) of Directive 2008/98/EC from private households subject to separate collection as defined in Article 3(11) of that Directive. (d) Biomass fraction of industrial waste not fit for use in the food or feed chain, including material from retail and wholesale and the agro-food and fish and aquaculture industry, and excluding feedstocks listed in part B of this Annex. (e) Straw. (f) Animal manure and sewage sludge. (g) Palm oil mill effluent and empty palm fruit bunches. (h) Tall oil pitch. (i) Crude glycerine. (j) Bagasse. (k) Grape marcs and wine lees. (l) Nut shells. (m) Husks. (n) Cobs cleaned of kernels of corn. (o) Biomass fraction of wastes and residues from forestry and forest-based industries, i.e. bark, branches, pre- commercial thinnings, leaves, needles, tree tops, saw dust, cutter shavings, black liquor, brown liquor, fibre sludge, lignin and tall oil. (p) Other non-food cellulosic material as defined in point (s) of the second paragraph of Article 2. (q) Other ligno-cellulosic material as defined in point (r) of the second paragraph of Article 2 except saw logs and veneer logs. (r) Renewable liquid and gaseous transport fuels of non-biological origin. (s) Carbon capture and utilisation for transport purposes, if the energy source is renewable in accordance with point (a) of the second paragraph of Article 2. (t) Bacteria, if the energy source is renewable in accordance with point (a) of the second paragraph of Article 2.

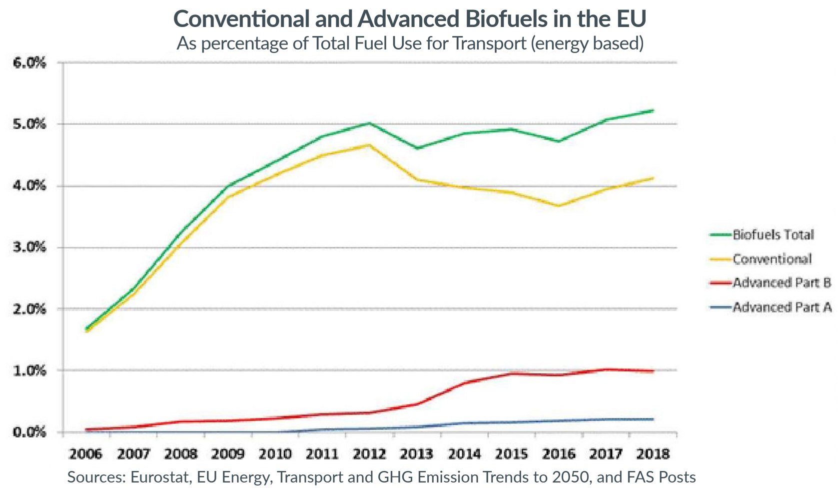


Figure 2: Conventional and advanced biofuels as percentage of Total Fuel Use for Transport 2006-2018 (USDA Foreign Agricultural Service)[8]

EC's communication on the 2030 Climate and Energy Goals from January 2014 did not include a specific target for the transport sector. This has changed with the recast of the RED. The trilogue between the European Council, Parliament and Commission reached a compromise in June 2018 for the new legislation called RED II (see page 16). New binding targets were set. These include legally binding 32% of renewable energy by 2030, 14% renewable energy is the agreed target for the transport sector. It was also set to phase out the palm oil use by 2030 and to freeze the food crop based biofuels at the level of production by each EU Member State in 2020. Advanced biofuels coming from non-food crops, wastes and residues have to count for 3.5% by 2030. Finally new sustainability criteria for biomass (including solid biomass) were discussed and set.

Whilst R&D on advanced biofuel technologies has made further progress since 2016, commercial deployment has stalled over the last years. The key reasons were the ongoing ILUC debate and uncertainties about RED II; low fossil oil prices were a further cause for a low appetite in investments. Also some key companies in the sector left the market, for reasons not directly linked to their advanced biofuel projects. With the political compromise about RED II, which still needs to be followed by proper legislation and national implementation, the framework for the next decade looks significantly clearer now. For further biofuels deployment there are still some key issues which need to be solved along the value chains. These will be presented in more detail in the following chapters. It is important to note that **the deployment of biofuels can only be pursued if the research within the different areas and aspects of biofuels is linked and collaborated actions are implemented.**

On the feedstock side, sustainable feedstock sourcing is the key challenge. More information about the resource efficient supply chain and competing uses for agriculture, forestry and wastes within other renewable sectors needs to be explored focusing at ways to improve mobilisation at different regional scales and at improved projections for 2030 and beyond. Currently, many different feedstocks are used for producing different biofuels; thus various conversion technologies are utilized. Specific value chains within this regional context differ and it is not possible to identify a 'one-size-fits-all' technology. In addition to the regional context of the biofuel production it needs to be taken into account that, the solution for an alternative fuel will differ across the different end-use sectors (road, air, marine).

A potential innovative approach could be to locally and sustainably pre-refine the biomass sources into high-quality biocommodities (pellets, pyrolysis-oil etc.) for efficient transport to more central secondary thermo-chemical and biochemical refinery processes for the production of advanced biofuels (and added-value products). To establish the renewable energy use in the transport sector further a mixture of liquid biofuels, blended biofuels with conventional fuels, natural gas vehicles, infrastructure converted to run on upgraded biomethane and the use of electric vehicle (electricity produced from renewables as well) has to develop. Regarding the technology side there are some biofuels which can be used in a state-of the-art internal combustion engine. For other fuels and alternatives to fossils fuels new alternative drive trains and technology has to be used and developed[9].

[8] https://gain.fas.usda.gov/Recent%20GAIN%20Publications/Biofuels%20Annual_The%20Hague_EU-28_7-3-2018.pdf

[9] REN 21- Renewable Energy Policy Network for the 21st Century . RENEWABLES 2018- Global Status Report. 2018. ISBN 978-3-9818911-3-3

2 INTRODUCTION AND STATE OF THE ART

Currently electric vehicles are judged as to be more attractive than biofuels to politicians and decision makers and the auto manufacturers are not that fond of biocomponents, although advanced drop-in type biofuels offer a fast-track option for decarbonizing transport. This focus on electric vehicles disregards several issues generating as high barriers as for more widespread use of biofuels, such as the change-out rate of the vehicle fleet, the need for new infrastructure down to the domestic level, the GHG emissions from power generation and possible scarcity of some key materials etc.
A more constructive approach forward would be to identify and pursue the synergies between electromobility and biofuels.

Currently EU ordinances to reduce CO_2-emissions from passenger cars (EU 2014)[10] are no real incentives for the auto manufacturers to produce other alternative fuel vehicles than electric vehicles. For a fair competition with Electric Vehicles (EV), EVs as well as biofuel powered internal combustion engine (ICE) vehicles should be evaluated on a well-to-wheel basis for GHG emissions as well as cost-effectiveness taking into account all the investments needed. The implementation of biofuels into the market still needs relevant incentives through demand setting i.e. blending mandates. Additionally, some transport modes such as aviation, are relying on liquid fuels, and even if there is currently a global trend towards a "more electrical aircraft", the propulsion part will still rely on these liquid fuels for a long time. In 2016 the Carbon Offsetting and Reduction Scheme for International Aviation in short CORSIA was adopted from the International Civil Aviation Organisation (ICAO). It is supposed to complement the basket of mitigation measures which the aviation industry and community are already pursuing in order to reduce the CO_2 emissions of the sector. These mitigation measures comprise technical and operational improvements and progress within the production and the actual use of Sustainable Aviation Fuels[11]. Advanced drop-in biofuels are consequently compulsory in order to meet future aviation ambitious greenhouse gas emissions reduction targets.

When progressing from research into the demonstration phase a larger focus needs to be put on additional aspect besides just the development of technology. This also applies to the form of projects where "new" actors (along the value chain as well as policy) need to be involved for long term success. Technology development focused on feedstock flexibility and integration with existing industries will not be enough. It needs to be coupled to research and development regarding markets, business models, novel value chain cooperation, policy instruments etc.
Technology and market development need to go hand in hand. This could be addressed to both forms (supporting and collaboration actions) and focus/content in R&D projects (cross-disciplinary research projects as well as "conventional" research projects).

It is important to realise that there should not be an adversarial set-

[10] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2014.103.01.0015.01.ENG

[11] SGAB. Final Report. Building Up the Future. Sub Group on Advanced Biofuels. Sustainable Transport Forum. . [Online] Juli 2017. [Cited: 21 August 2017.] http://platformduurzamebiobrandstoffen.nl/wp-content/uploads/2017/07/2017_EC_SGAB_Building-Up-the-Future_Final-Report.pdf

up between biofuels or any other energy carrier. The important thing is that starting from a baseline of over 90% fossil energy in transport in 2020, the need to increase the share of renewable energy is evident for all energy carriers. So far, the competitor within the transport sector is fossil fuel, 88% of oil imports account for the transport sector and the European dependence on imported oil is still increasing. It should be made visible that, depending on origin, feedstock and processes used, also fossil fuel has an impact on sustainability (e.g. social impact). Therefore, similar criteria and performance should be investigated and made transparent for fossil fuels to allow fair competition. Indirect cost, often referred to as externalities are brought to the society with the use of fossil energy carriers. These include human health problems caused by air pollution from the burning of coal and oil; damage to land from coal mining; environmental degradation caused by global warming, acid rain, and water pollution; and national security costs, such as protecting foreign sources of oil. The producers and the users of energy do not pay for these costs, society as a whole must pay for them.

It is also important to highlight, that the deployment of biofuels does not only bring challenges but it also brings opportunities e.g. to decarbonize transport, boost economic growth and jobs and achieve steps towards energy security for Europe[12]. According to the EurObserv'ER Report[13] the 2016 EU biofuel sector sales turnover was €13.1bn and work force of around 205 000 workers (direct and indirect).

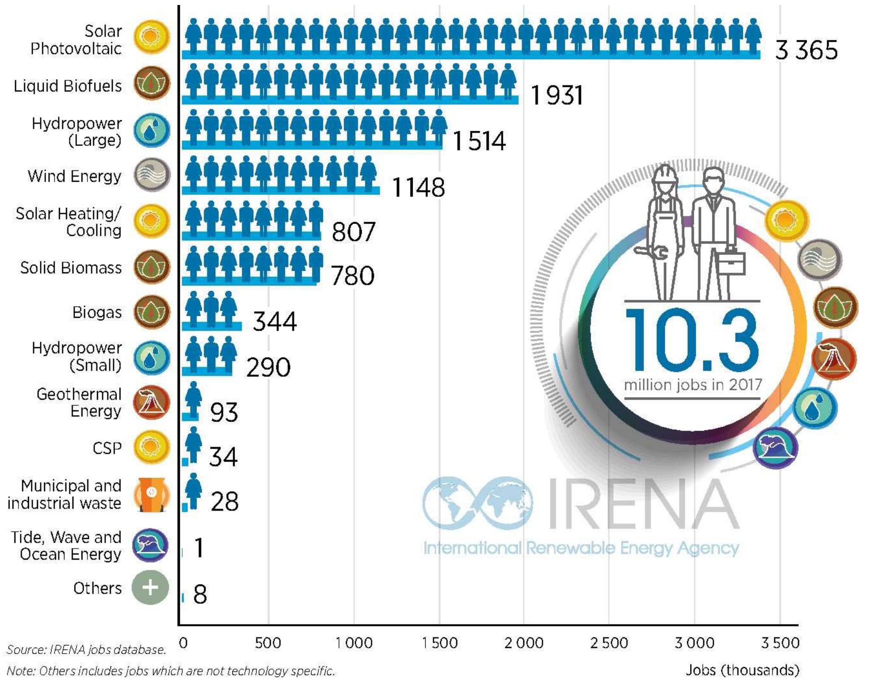


Figure 3: Global Employment Effects of Renewable Energy Deployment by Technology[16]

Employment effects are difficult to calculate and have to be interpreted carefully, e.g. regarding gross and net effects or direct, indirect and induced employment effects[14]. According to the IRENA Renewable Energy and Jobs Annual Review 2018, within the European Union 1.19 million jobs are estimated for the renewable energy sector. About 50% of Europeans jobs in the sector are accounted in 6 out of 28 Member States (Germany, France, Spain, Italy, Poland and Finland). 660,000 job units are estimated for bioenergy related jobs including biofuels, solid biomass and biogas in the EU, whereas in 2017 the worldwide biofuels employment expanded by 12% to 1.93 million jobs mainly related to the agricultural value chain. In principle employment trends and pattern are encouraged by a wide range of technical, economic and policy driven factors. Still a key factor represents the governmental policy and its commitment to transform the energy sector[15].

It will be necessary to identify synergies between both fully established and developing biofuel industries, and the deployment of innovative biorefinery concepts for the sustainable use of biomass for both bioenergy and biobased products production.

[12] Ecorys et al (2017) : Research and Innovation perspective of the mid - and long-term Potential for Advanced Biofuels in Europe; European Union; 2017;ISBN 978-92-79-70565-6 (https://publications.europa.eu/en/publication-detail/-/publication/448fdae2-00bc-11e8-b8f5-01aa75ed71a1/language-en)

[13] https://www.eurobserv-er.org/pdf/annual-overview-2017-en/

[14] IEA-RETD Policy Brief on Renewables and Employment, 2012

[15] https://irena.org/-/media/Files/IRENA/Agency/Publication/2018/May/IRENA_RE_Jobs_Annual_Review_2018

[16] Renewable Energy and Jobs annual Review 2018; IRENA, http://irena.org/-/media/Files/IRENA/Agency/Publication/2018/May/IRENA_RE_Jobs_Annual_Review_2018

It should be kept in mind that every new biorefinery creates approximately 100 direct jobs and up to 1,000 more in ancillary services like maintenance and transport[17]. In 2017 Martin et al. assessed the environmental benefits from by-product and utility synergies in the Swedish biofuel industry[18,19].

Expected benefits from biofuel production regarding job creation lead to an underestimation of the contribution of biofuels to reduce GHG emissions and other environmental impacts when replacing fossil fuels[20]. During the construction phase and in terms of average plant lifetime, jobs will be created as long as the economy is facing an output gap. If the prior policy aim was to spur job creation, the construction sector has a greater potential than the renewables sector, considering numbers of jobs created in a monetary investment perspective.

However, in a long-term the benefits of renewable energy and energy efficiency should be taken into account. Moreover, jobs in the renewable energy sector have the potential to reducing environmental externalities and creating dynamics of technology development pathways and lead to a desired structure of the economy[18]. Thus, a wider consideration should prevail when discussing the long term role of renewable energy and energy efficiency that includes a wider framework of energy and environmental policy and not only a narrow analysis of the impact of green jobs. In the future, biofuels and bioenergy will play a major role in the decarbonisation of the EU transport sector and it is vital to use the resources and technological assets at the best[21].

[17] https://www.epure.org/about-ethanol/ethanol-benefits/jobs-and-growth/

[18] http://www.f3centre.se/research/program/Environmental-and-Socio-Economic-Benefits-from-Swedish-Biofuel-Production

[19] https://www.tandfonline.com/doi/abs/10.1080/17597269.2017.1387752?journalCode=tbfu20

[20] Low carbon jobs: The evidence for net job creation from policy support for energy efficiency and renewable energy A report for UKERC by UKERC Technology & Policy Assessment Function Will Blyth Rob Gross Jamie Speirs Steve Sorrell Jack Nicholls Alex Dorgan Nick Hughes; http://www.ukerc.ac.uk/asset/0A611DB6-DCEA-4628-97FC16042EAD4F20/

[21] ibid

3 MARKETS, REGULATORY FRAMEWORK AND PUBLIC AWARENESS

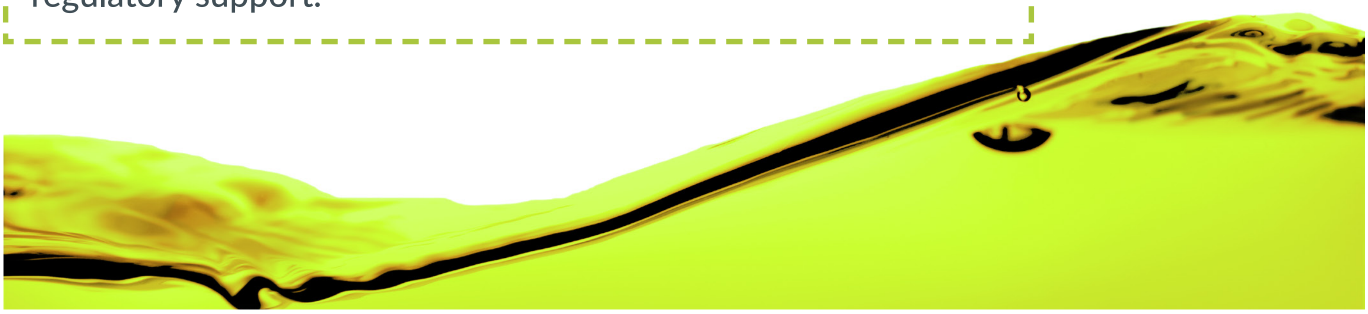
MAIN RECENT DEVELOPMENTS

So far the biofuel market for transport was regulated by the directive on the quality of petrol and diesel fuels 2009/30/EC (FQD[22]) and the directive promoting the use of renewable produced energy 2009/28/EC (RED[23]) from 2009. The ILUC debate and long delay in revising these directives had created market uncertainty, and reduced investors' confidence, only partly solved by the ILUC directive from September 2015. These current legislations set the mandatory goals for renewable energy until 2020 on which one is the 20% share of renewable energy and a 10% blending target for renewable transport fuels. The RED also defines suitable sustainability criteria for liquid fuels, sets a 7% cap for food crop-based biofuels and included a non-binding target national target for non-food based (advanced) biofuels of 0.5%.

On 30 Nov 2016, the European Commission made a proposal for the recast of the RED post 2020, the so called RED II directive. After 19 months intense debate, the European Council, Parliament and Commission found a political compromise for RED II in June 2018.

This will be brought into proper legislation by the end of 2018 and will then be transposed into national laws by the Member States. The RED II directive also opens up for the use of renewable fuels, even if the exact definition and delimitation is still subject to negotiations, and provides a global target for advanced biofuels, biofuels, renewable fuels and RE electricity used in transport of 14% in 2030, but some of the fuels are associated with double-counting factors and some are not, while also for aviation fuels and RE electricity used in transport are associated with different weight factors. However, RE electricity in transport is not expected to contribute more than 2% absolute of the target in 2030[24] .
The GHG reduction requirements in the FQD will be discontinued after 2020.

In recent years, prices for both crude oil and agricultural commodities have been highly volatile (with a strong interrelation between the food price index on energy prices, irrespective of the biofuels demand). Overall, crude oil prices stayed significantly below earlier forecasts. Thus, even though the first European countries started to introduce biofuels 20-25 years ago, biofuels are not yet ready to compete at a global scale without adequate regulatory support.



[22] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32009L0030

[23] http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32009L0028

[24] EU Reference Scenario 2016 –Energy, transport and GHG emissions - Trends to 2050.
DG ENER 2016: https://ec.europa.eu/energy/sites/ener/files/documents/20160713%20draft_publication_REF2016_v13.pdf

Infobox 1: Existing EU biofuels framework

The EU biofuel framework

The Renewable Energy Directive 2009/28/EC (RED):

- Every EU Member State has to achieve a 10% energy content target of renewables in transport by 2020 using biofuels, renewable electricity or hydrogen
- Biofuels from waste, residues, cellulosic and lignocellulosic material count twice towards the 10% target
- Bonus of 29 g CO_2/MJ for biofuels from degraded/contaminated land when estimating the GHG emission reduction rel. the fossil comparator

The Fuel Quality Directive 2009/30/EC (FQD):

- Fuel suppliers/blenders have to reduce by 6% reduction of the GHG intensity of all fuels put in the European market by 2020, an objective that fuel distributors are expected to meet by blending biofuels and reducing upstream emissions or UERs
- Environmental quality standards for a number of fuel parameters,
- Standards for blending biofuels:
    - 10% ethanol in petrol (E10) with transitory regulations (protection grade E5) for older cars and derogations for petrol vapour pressure subject to EC approval
    - 7% biodiesel in diesel (B7) by volume, with an option for more than 7% with consumer info
- Mechanism for reporting and reduction of the life cycle GHG emissions from fuel

Sustainability criteria: To qualify for both FQD and RED II targets, biofuels need to meet sustainability criteria:

- A minimum GHG emissions savings of 35% compared to fossil fuel, rising to 50% in 2017 and 60% for new installations on-stream after 2017.
- Restrictions on the types of land converted to the production of biofuels crops (land with high biodiversity value and high carbon stocks are no-go areas). The latter criterion covers direct land use change only.
- Sustainability criteria for forest biomass- LULUCF accounting
- CHP requirements to reduce pressure on limited forest biomass resources and promote resource efficiency

New provisions brought by the ILUC Directive (2015/1513/EC)

- No ILUC factor in GHG calculation but a public reporting obligation from 2020
- 7% cap on conventional biofuels (from crops) in energy content:
    - Every Member State (MS) can account a max of 7% of crop-based biofuels towards the 10% target of renewables in transport by 2020
    - A MS can decide to set a lower cap than 7%
    - A MS can also decide to apply the 7% cap to the FQD
    - Possibility of setting out criteria for the identification and certification of low ILUC crop-based bio fuels beyond that could be eligible beyond the cap
- 0.5% indicative sub-target for advanced biofuels:
    - Each MS should set up a national target of 0.5% advanced biofuels by 2020 within 18 months of the entry into force of the Directive, i.e. 6 Apr 2017
    - The 0,5% is double counted and would count 1% towards the 10% target
    - MSs may set a national target lower than 0.5% under certain conditions (limited potential for sustainable production or availability, more incentives to efficiency or EVs, etc)
    - UCO (Used Cooking Oils) and animal fats are double counted but not eligible within the 0.5% target

The Renewable Energy Directive II (RED II) after the trilogue from June 2018:

- - 40% GHG emissions including LULUCF
- 32% target for renewable energy but will be reviewed in 2023
- 14% target for renewables in the transport sector
- Phase out of palm oil use until 2030
- 7% cap for conventional biofuels. Member States who decide to set this cap lower than 7% are allowed to also reduce the overall 14% target with the same number of percent points.
- Mandate for the advanced biofuels will be set at 0.2% in 2022 which will rise by 2030 up to 3.5% (given double counting effectively 0.1% and 1.75%, respectively). Other multipliers that will be used: 1.2 for aviation, 1.5 for rail and 4.0 for electricity in EV's.
- Member States allowed to transpose the targets differently into national regulations, which means it is a flexible implementation
- New and adjusted sustainability and greenhouse gas emissions saving criteria for biofuels, and bioliquids and biomass fuels

Different regulatory frameworks including sustainability requirements and support for advanced technologies are being developed actively in some countries. For example, Italy and Finland established ambitious policy frameworks in support of advanced biofuels. Germany on the other hand has decided to focus on GHG performance by implementing the FQD as the main policy tool to achieve its 2020 targets (see EBTP report on Post-2020 Visions and National Plans for Sustainable Transport[25]).
Today, low carbon requirements and market incentives focus essentially on GHG performance, with additional efforts to include other factors such as biodiversity protection. There is likelihood that the RED will not be comprehensively and uniformly implemented in the Member States. Furthermore, it is not clear whether all Member States will achieve 10% renewable in transport and 6% reduction in GHG emissions of fuels by 2020 in the absence of specific transport framework by 2030.

In addition, the Directive on the deployment of alternative fuels infrastructure (2014/91/EU of October 22, 2014) requires Member States to develop national policy frameworks for the market development of alternative fuels and their infrastructure; and fuel labelling in order to improve the development of biofuel distribution and consumers' information. There are difficulties in realizing demonstration and first-commercial plants in Europe even with financial aid.
The NER300[26] funding for risk sharing of innovative flag ship projects has so far materialized in only two biofuel projects which reached final investment decision (BEST Italy, Verbiostraw Germany)[27].
Legislative stability (over timeframes of well over 10 years) is an essential requirement as a favourable investment condition for biofuel production plants.

As part of the Energy Union Strategy presented in February 2015, (EC 2015)[28], the European Commission provides some hints on the role of biofuels post 2020. The Energy Union stresses that the EU needs to invest in advanced, sustainable alternative fuels, including biofuel production processes, and in the bio-economy more generally. It also highlights that the EU will need to take into account the impact of bioenergy on the environment, land-use and food production. When it comes to the decarbonisation of transport – the focus of the Energy Union is on electro-mobility, which has been deliberately granted a zero emission footprint, regardless of the impact of the source of electrical energy or the actual life cycle emissions of that transport modality. As a follow up to the Energy Union, a Communication on the decarbonisation of transport and a revision of the Renewable Energy Directive has been presented on 30 November, 2016 which led to the RED II directive (see page 13) [29]

RECOMMENDATIONS

It is urgent and critical to prevent the European bioindustry and bioeconomy from loosing their importance and competitiveness at the international level. Post 2020 liquid transportation fuel and combustion engines will still make up by far the majority of road transportation in both light and heavy duty vehicles as well as in aviation and marine transport. A pragmatic and long-term 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. In addition it should not penalise the EU biofuels industries against the other regions and continents or for that matter unfairly against other alternatives like EV. The political agreement on the Renewable Energy Directive recast in June 2018 (RED II) is a key step in this direction.

It is important to take into account that several national energy and transport policies are being developed for the horizon 2030 –

[25] http://www.etipbioenergy.eu/images/ecn-sustainable-transport-visions-beyond-2020.pdf accessed 31 July 2018
[26] http://ec.europa.eu/clima/policies/lowcarbon/ner300/index_en.htm
[27] See e.g. http://artfuelsforum.eu/wp-content/uploads/2017/05/NER-300-Initiative-and-Status-of-Bioenergy-Projects.pdf accessed 31 July 2018
[28] https://eur-lex.europa.eu/resource.html?uri=cellar:1bd46c90-bdd4-11e4-bbe1-01aa75ed71a1.0001.03/DOC_1&format=PDF
[29] https://ec.europa.eu/energy/en/topics/renewable-energy/renewable-energy-directive

in line with the Energy Union, and the Directive on the deployment of alternative fuels infrastructure (2014/94/EC)[30].
These policies need to be harmonised where necessary to avoid fragmentation and ensure reliable interconnection for transport (and fuel distribution). This will be a key issue for the national implementation of RED II.

Land use change, low and high ILUC biofuels and other sustainability criteria must still be further clarified. In addition rules for more explicit checking and for sustainability certification should be implemented and tested in Europe and outside Europe as it is probable that imports from other regions will occur. Linking sustainability criteria and certification to the development of an international trading market for sustainable biocommodities potentially would accelerate the market deployment of full biomass-to-products value chains, incl. those focusing on advanced biofuels. High-potential biomass sources (high volumes, low prices), like agro/process residues and grassy crops grown on marginal lands in and outside Europe could be made available in this way to meet the market of the future Biobased Economy, coproducing bioenergy/fuels and biobased products in a sustainable and synergistic way.
For innovative biofuel and bioenergy technologies, continued R&D support should be ensured through existing EU and national instruments. High-risk demonstration and reference plants require adequate investment schemes (grant, loans, fiscal incentives) to allow funding e.g. via public/private partnerships. Policy makers must create favourable investment conditions with clear messages for the massive industrial investments that are required for decarbonisation in Europe.

It is also necessary to increase public funding and to strengthen support of R&D on sustainability related tools and data.
Develop the appropriate, highly specialised professional skills that are required for the bio-industry. This relates to education, training and a better knowledge transfer from science to practice, but also the knowledge exchange and cooperation between the different disciplines and parties in a value chain[31].
Importantly as well, initiatives to inform and explain to the wider public the benefits of biofuels and bioenergy in general on the economy and on the Society (and the ongoing efforts to minimise their pitfalls) shall be encouraged and supported.
The complexity of biofuels issues as well as the significant potential is not yet fully understood by the wider public. This remains a critical issue that the sector has to deal with. The launch of the website www.BiofuelsforEurope.eu on June 23, 2015 is one example of initiative that can provide better information to the European audience.

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

[30] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32014L0094

[31] In line with the recommendations from the FP7 EU funded project, BIOTIC (see http://www.industrialbiotech-europe.eu/new/wp-content/uploads/2015/09/Non-technological-Roadmap.pdf

main reason ("food vs. fuel" discussion). Developments in Life Cycle Analysis (LCA) have shown that there are no "real" pathways in Europe that result in biofuels at least as CO_2 intensive as conventional fossil fuels. Perceived environmental and social issues related to biofuels remain high on international agendas though real world results are actually giving cause for optimism. Further examination of real world results are required so that the successful models are reinforced, lower performing models phased out and stakeholders made aware of actual conditions in the field. 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 way. Improving industry openness is an easy and quick way to enhance public confidence. A similar debate has taken place in relation to bioenergy in general, starting with the use of maize and other energy crops for biogas production and going up to the "carbon debt" discussion for woody biomass[32].

Both the public perception on biofuels' and bioenergy's sustainability and the potential competition with other biomass applications (food, feed, chemicals and materials) represent important elements limiting the expansion of the bioenergy/biofuel technologies, and need to be addressed under a global perspective.

It is critical to encourage and support communication initiatives aiming at explaining to the wider public the benefits of biofuels and bioenergy as well as their potential pitfalls and the efforts deployed to mitigate them. For example, a Bio(based) Economy cannot exist without bioenergy, which will be the lubricating oil to make it work.

Policy makers and stakeholders should invest efforts into informing the public of the values and impacts of large scale bioindustrialisation in Europe.

[32] See e.g. http://www.ieabioenergy.com/iea-publications/faq/woodybiomass/ accessed 31 July 2018

RECENT DEVELOPMENT AND FACTS

- The Renewable Energy and Fuel Quality Directives (RED and FQD, see Infobox 1 below for more details) have set the regulatory framework for biofuels up to 2020 in the EU. The ILUC directive from Sep 2015 (2015/1513/EC) puts a 7% limit on biofuels from crops and sets an indicative target for advanced biofuels at 0.5% (energy content) for 2020.
- Member States' implementation of the above directives was expected to provide greater clarity on renewable fuel and energy mix targets at national levels. So far implementation varies largely with some countries lacking behind considerably. Some novel approaches focus on GHG performance of biofuels instead of an energy share.
- The failed tax directive has resulted in a distorted market for biofuels.
- The RED II political compromise from 13 June 2018 sets a target of 14% renewable energies in transport by 2030, limits biofuels from food crops to level at a 2020 datum (+1%) and introduces a sub quota for advanced biofuels increasing from 0.2% in 2022 to 1% in 2025 and to 3.5% in 2030 (which, as advanced biofuels count twice, is effectively 0.1, 0,5 and 1.75%).
- There is an emerging trend to include the full LCA scope for vehicles when it comes to energy use and production. A way to explore this further could be to have an EU working group that benchmarks LCA for both electric and non-electric vehicles.
- The countries' approach and implementation of strategies towards meeting their Paris Agreement ambitions has significant importance for investment in bioenergy. From this context, countries such as Sweden and Finland have already expressed higher ambitions for advanced biofuels in 2030 than needed to meet the EU targets and directives.
- Cost effective tools for effort sharing under the EU climate and energy policy[33] and the role of bioenergy in that needs to be explored.
- Renewable fuels can contribute significantly in the short term and act as a transition tool away from fossil fuels. If long-term passenger transport may be dominated by battery and hydrogen electric vehicles, biofuels application in this sector is still be a useful step-up for their application sector where they remain needed on the long term, viz. aviation, shipping and heavy-duty freight transport.
- The Energy Union stresses that the EU needs to invest in advanced, sustainable alternative fuels, including biofuel production processes, and in the bio-economy more generally. It also highlights that the EU will need to take into account the impact of bioenergy on the environment, land-use and food production. The integrated SET-Plan[34] and its update in 2018[35] aim to accelerate the deployment of low-carbon technologies and recognise the need for development, scale-up and deployment of biofuels.
- When it comes to the decarbonisation of passenger transport, the focus of the Energy Union is on electro-mobility, which has been granted a zero-emission footprint regardless the source of electrical energy. This leads to an uneven playing field for renewables.
- The Directive on the deployment of alternative fuels infrastructure (DAFI; 2014/94/EC) requires Member States to develop national policy frameworks for the market development of alternative fuels and their infrastructure; and fuel labelling in order to improve the development of biofuel distribution and consumers' information. DAFI does not enforce the build-up of dedicated biofuel infrastructure. For biofuels it is relying on low blends of biofuel that don´t need new infrastructure. Mandating E85 and other high biofuel blends along major routes would significantly contribute to creating a market for vehicles dedicated to the utilization of such higher biofuel blends.
- Rebound effects: Although the carbon intensity per kilometre driven in LDVs is decreasing due to the use of biofuels and the limits for tailpipe CO_2 emissions, the overall emissions from the sector are not decreasing because of increasing mileage. The increased mileage is also an effect of economic growth.
- The complexity of biofuels issues, specifically within the framework of a further developing Bio-Economy, synergetically and sustainably co-producing bioenergy/biofuels AND food/feed ingredients, chemicals, materials are not yet fully understood by the public.

[33] https://ec.europa.eu/clima/policies/effort_en accessed 31 july 2018

[34] http://ec.europa.eu/energy/en/topics/technology-and-innovation/strategic-energy-technology-plan

[35] Section 8 ref.

RECOMMENDATIONS

- Develop regulatory and financing tools to overcome the hurdles for demonstration and first-commercial plants
- Make sure that with the RED II implementation a clear, stable and consistent policy framework for the long term (post-2030) is established, starting with simple, meaningful, quantifiable objectives and measures
- RED II implementation should stimulate sustainable biomass strategies e.g. encouraging integrated biomass applications, taking into account the overall goals defined at the political level.
- Consider efficient and sustainable use of biomass sources for the production of both food/feed ingredients, chemicals, materials AND fuels and energy in a synergistic way by using high-efficiency market-driven biorefining approaches.
- GHG emission quotas for fuels, both on a Member State level and for the fuel batches brought to the market, are a good instrument but should be set to ambitious reduction targets. These should be increasing regularly however also providing investment security.
- Multiple counting of specific biofuels or other renewable energy in the transport sector has not been effective in supporting the production of advanced biofuels so far. It is trying to direct ambitions to certain fuel-vehicle combinations. If effective, they dilute the possible GHG emission reductions that are achievable with a certain target of RES in the transport sector. Multiple counting also makes communication with the public on the perceived and real impact of biofuels difficult. As multiple counting is foreseen in RED II, these aspects should be addressed in national implementation and other incentives for advanced biofuels will be required.
- Biofuels and advanced biofuels should be recognized, in parallel to e-mobility, as an important tool to decarbonize transport. However, it should also be recognized that even long-term, biofuels are one of the very few options to decarbonize certain means of transport, electricity, industry and agriculture.
- Link the sectorial "silo" structures of transport, electricity, industry and agriculture in order to increase the success of research and investment in EU.
- For sustainability related tools and for innovative biofuel and bioenergy technologies, ensure continued R&D support. Develop and broaden relevant investment schemes such as public-private partnerships to allow funding of risky demonstration and reference projects (e.g. InnovFin, SET-Plan Action 8, Innovation Fund).
- Encourage and support initiatives at all level (regional, national and EU wide) to inform and explain to the wider public the benefits and necessity of sustainable biofuels in EU.
- The production of biofuels delivers much more to society than low-carbon fuels alone; brings many other services such as employment along the value chain, income to farmers, outlets for residues, a portfolio of co-products, up to possible points for CCS or CCU (high purity CO_2 available at biofuel production facilities) and possible grid balancing services. These services should be better communicated and policy should find ways to pay for these services.
- As climate change is our largest concern at the moment, GHG emission reduction should be used as the main criteria for giving support to technologies or fuels. The list of feedstock' in Annex IX should be amended accordingly without jeopardising investment security regarding the current list.

RECOMMENDATIONS

- Develop sustainable biomass sourcing strategies, incl. robust technologies for the production of and an international trading market for high-quality biocommodities, to be able to provide sufficient biomass sources at the right place and time, and for an acceptable price.
- Each country should undertake techno-economic studies about the options to decarbonise the transport system as they have been made e.g. as the basis for the policy in Finland. To achieve their renewable energy targets the country concluded that it benefits most if producing biofuel in national facilities from national feedstock. Also it has calculated that the contribution of electric vehicles alone – even if only selling EVs from tomorrow on – will not be sufficient to reach the RES targets in 2030. Biofuels and electric vehicles will have to complement each other in order to reach the goals. There is no one size fits all – each country has to make its own assessment and define which measures are the best for its current situation.
- Introducing a common mass balance system accepted by the EU and all MS to account for the biogenic content of transport fuels that are co-produced in refineries would support the integration of biofuel production into fossil refineries. Without major investment costs, GHG emissions of the fuel produced could be reduced. It is recommended that the EC should produce a delegated regulatory act by 2021.
- Go for binding targets for GHG emission reductions in both international transport sectors of aviation and shipping. Voluntary schemes are not likely to deliver, and planting trees might be much easier than sourcing and paying for biofuels.
- As several national energy, climate mitigation and transport policies are being developed for the horizon 2030 – in line with the Energy Union, and the Directive on the deployment of alternative fuels infrastructure (2014/94/EC) and RED II, try to harmonise the implementation of these policies in the EU/EEA area where necessary to avoid fragmentation and ensure reliable interconnection for transport (and fuel distribution)
- Ensure a coherent approach for carbon accounting under RED II and under CORSIA for the aviation sector.
- Ensure a swift and reasonable transposition of European directives at Member States level.
- It is necessary to develop a systemic view of the transport sector to ensure that technology evolution is not offset by changes in consumer behaviour. Social sciences need to be applied.
- More facts are needed in order to highlight the important role of bioenergy and renewable fuels. Influencers' views are unbalanced and negative towards renewable fuels.
- Highlight the synergies between electromobility and renewable fuels.
- Develop the appropriate, highly specialised professional skills that are required for the bio-industry[36].

[36] In line with the recommendations from the FP7 EU funded project, BIOTIC (see http://www.industrialbiotech-europe.eu/new/wp-content/uploads/2015/06/BIO-TIC-roadmap.pdf)

4 SUSTAINABILITY

MAIN RECENT EVOLUTION AND FACTS

Sustainability has already been identified as a key challenge for biofuels by the EBTP in the original 2008 SRA/SDD. 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 referring to RED II, ILUC directives and likewise to forestry LUCLUF (see chapter 3 for a more detailed introduction to RED and FQD).
With the new RED II new sustainability and greenhouse gas emissions saving criteria for biofuels, and bio-liquids and biomass are confirmed and expanded.

The objectives of these criteria are:

- to minimize the risks of negative environmental impacts (e.g. deforestation, degradation and biodiversity),
- to cover all bioenergy uses including heat and power and biofuels,
- deliver optimal greenhouse gas savings compared to fossil fuels,
- to promote resource efficiency and avoid market distortion
- to ensure proportionality cost effectiveness by applying a risk-based approach and minimum thresholds for bio-heat and power plants.

The new criteria include beyond biofuels and bio-liquids to cover also solid biomass and biogas for heat and power. The compliance with the sustainability criteria is a necessary condition to count for the renewable energy share at the EU and at the Member States`levels. This will be covered by the renewable energy obligations which identify fuels that are eligible for financial support. Bioenergy produced from waste and processing residues only needs to meet the GHG saving criteria. In principle the sustainability and GHG criteria count for all biofuels and bio-liquid installations, solid biomass installations with fuel capacity equal or above 20 MW and biogas installations with a fuel capacity equal or above 0.5 MW (article 26, paragraph 1). Member States cannot set additional or different criteria for biofuels or bio-liquids, whereby for biomass fuels additional sustainability criteria can be introduced. They are also allowed to set lower capacity thresholds at national level.

In the new RED II updated sustainability criteria for agriculture biomass are included additionally to new criteria for forest biomass.

Indirect Land Use Change (ILUC) factors have been **debated over several years and were not included in the ILUC directive from 2015**[37]. A provisional estimation of ILUC emissions from biofuel and bioliquid feedstocks (gCO_2eq/MJ) was maintained in the final text for reporting by the Commission, and not for assessing regulatory compliance. This reporting is based on ranges taken from Monte Carlo analysis by the International Food Policy Research Institute (IFPRI). The new RED II includes stipulations for limiting so called "food-crop-based biofuels" to their use in 2020, and phasing out high ILUC risk biofuels e.g. based on palm oil. RED II has to be seen also in the frame of an expanded LUCLUF legislation.

Many questions e.g. regarding direct and indirect land use or the definition of biodiversity, soil, water social criteria remain open until today. So far, certification criteria have been established in several Member States, in line with the conditions given in the Renewable Energy Directive but clarity and coherence across Member States is necessary. It is important to work towards international harmonisation and/or procedures for mutual recognition of sustainability criteria at a global level. This is particularly important as transport is global, especially aviation. This is also important as certification comes with transaction costs for each change of custody along the value chain down to individual farmers etc. whereas other areas where biomass or fossil fuels are used are not generally subject to similar cost.

[37] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32015L1513

POLICY RECOMMENDATIONS

Greater EU regulatory clarity and coherence across Member States are necessary (with the goal of reaching a European regulation regarding sustainability). A uniform set of sustainability criteria is desirable. In addition, continuous dialogue at international level, including NGOs, is needed to achieve compatible standards on actual sustainability performance, possibly resulting in a globally recognized ISO standard. Finally, sustainability criteria should apply to all biomass uses to allow a level playing field between energy, food and other applications. Practical initiatives to deal with this should be supported as long as they do not increase market fragmentation. In the same time unneccesary complex criteria and the related administrative burden for operators should be avoided.

It is increasingly recognised that sustainability requirements for bioenergy/biofuels restricts biomass sourcing for bioenergy/biofuels purposes, as do competing usages (food, feed, fibre). As a consequence, consensus seems to emerge that biomass sustainability should be considered holistically, for all its applications, including food and feed, as should land use issues. Besides, adequate sustainability requirements are critical to ensure the long-term availability and competitiveness of biomass. While the scientific debate on quantifying ILUC remains polarised, practical initiatives exist that aim at preventing undesired land use change impacts of biomass use, often at a regional level, such as the Sustainable Biomass Regions (see infobox 2) concept. **Developing strategies to safeguard sustainability on the ground may prove to be more relevant than a continuous discourse over system-wide analyses of (i)LUC.**

In the light of recent discussions on sustainability and regarding feedstock risk management in medium and longer term investments in research, development and especially implementation of technologies it is important to notice that certain guidelines can be drawn to mitigate the risks. The challenge in the wider debate is that biomass feedstock is not a uniform concept. Different biomass feedstocks have varying impact and tradeoffs between different UN SDGs (United Nations Sustainable Development Goals). Regarding these environmental and societal risks, it can be stated, that there are certain biomass fractions that can be, with great certainty, classified as low risk feedstock. In contrast there are other fractions that can be identified with great certainty as having negative impacts on the environment and on the society. In between are biomass fractions for

Infobox 2: Sustainable Biomass Regions

Sustainable Biomass Region is a concept that is being explored to help develop sustainability systems at a larger scale. According to the Bioeconomy Panel, a Sustainable Region would follow a series of principles on a regional level: focus on greenhouse gas reduction, prevention of soil degradation, and possibly restoration; optimisation of agricultural, forestry and aquatic production; a regional strategy to prevent environmental harm and to facilitate social and economic growth. One of its elements can be that additional biomass for energy is produced on the condition that additional regional biomass productivity increases allow this to be produced without jeopardising food and feed security or inducing land use change.
In an ideal end picture, a guarantee of origin from a Sustainable Region would be enough to prove the product is sustainable.
The Sustainable Biomass Regions could be a strategic initiative to help developing sustainability systems at a larger scale. Harmonisation of standards for sustainability at EU level represents a key driver to stabilise the sector in the long run, ensure a wider recognition of the biofuels industry and channel investments.

which we need more information and for which therefore the probability of risk is higher: **These feedstocks should be exploited only if, at a later time, they are eventually identified as low risk.** This approach is described as a bioenergy corridor that clarifies where development should be directed, and that there are bioenergy options that are safe and can be immediately promoted. This approach, to better use biomass should also be considered in relation to the GHG impact and the urgent need to reduce fossil GHG emissions.

It should be made visible that, depending on origin, feedstock and processes used, also fossil fuel has an impact on sustainability (e.g. social impact). Therefore similar criteria and performance should be investigated and made transparent for fossil fuels to allow fair competition.

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, based as much as possible on real data (demonstration or industrial-scale projects). This applies to the full chain of biofuel production, from feedstocks to end uses and to integrated production of multiple products, to EU domestic and imported feedstocks and fuels, and to the three dimensions of sustainability (environmental[38], social and economic). There will definitely be a trade-off between fully safeguarding sustainability and the need to avoid overly complex criteria and the related administrative burden. Innovation will be needed to reconcile these two aspects.

For the idea of a sustainable biomass corridor described above, more information on different biomass origins and qualities is needed. It might be supportive to distinguish between:

- technical biomass sourcing potential (MT db or GJ per ha): the amount of biomass that is available at an area
- economic biomass sourcing potential: the amount of biomass that can be contracted from an area taking into account competing claims
- sustainable biomass sourcing potential

The concept of Sustainable Biomass Regions has not been fully elaborated yet but deserves further RD&D support. This would be particularly important for conventional biofuels, as the sustainability concerns related to them mainly lie in the availability of sustainable feedstock.

For advanced biofuels, technology RD&D support seems more logical, as they have significant potential to provide biofuels from sustainable low-grade feedstock, but their key challenges lie in further technology development.

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. How information can be verified and what rules to develop for certification bodies represent another important aspect.

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 of high quality should be a priority for public R&D funding at EU and national level.

[38] (GHG, CO_2, N2O, CH4, water, biodiversity, local emissions, soil, etc.)

MAIN RECENT DEVELOPMENT AND FACTS

- Certification schemes for sustainable biofuels have been established in several Member States, in line with the conditions given in the Renewable Energy Directive[39,40].
- In EU policy, the debate on ILUC has been settled (see the regulations chapter) and no ILUC factors were included in the RED from 2009 and the ILUC directive from 2015 for lack of scientific conclusiveness and general agreement on this aspect. However, several questions remain open (direct and indirect land use, definition of biodiversity, soil, water, forest carbon balances and the related sustainability of forestry materials, social criteria, etc.). All in all, it is still unclear how certification systems will develop further, and which ones will become the most adequate and consensual. Low ILUC land use schemes have been investigated and RED II foresees delegated acts on ILUC in 2019 and 2023[41].
- It is increasingly recognised that sustainability requirements are not only relevant for bioenergy/biofuels applications of biomass, but also for competing usages such as food, feed, biobased products (chemicals, materials, fibres) Therefore, a holistic approach should be pursued.
- More research and data are still necessary to improve existing sustainability criteria and develop new land management strategies, in order to ensure the long-term availability and competitiveness of biomass.

POLICY RECOMMENDATIONS

- Greater EU regulatory clarity and coherence across member states is necessary, as is renewed commitment to the goal of a single EU market for liquid transport fuels. It should be recognised that the regulatory demands for certification introduces additional costs to the industry along the value chains down to e.g. small-holders.
- Guidelines should be developed per major feedstock category (agriculture, forestry, biowaste) at project implementation level, and also including co-processing options, to improve clarity both for biomass producers and industry. Consider the idea of a sustainable biomass corridor.
- Continued dialogue at international level is needed to achieve compatible standards on actual sustainability performance of feedstocks, possibly resulting into an ISO standard.
- Standard should be set with criteria and indicators that correspond to residue ratios, technical availability factors and sustainability criteria.
- Work towards application of sustainability criteria across all biomass uses to allow a level playing field between energy, food and other applications of biomass.
- Similar criteria and performance from a well-to-wheel sustainability perspective should be be investigated and made transparent for electrofuels, electricity driven transportation and hydrogen to allow fair competition.

[39] https://ec.europa.eu/energy/sites/ener/files/documents/ecofys_methodologies_for_low_ILUC_risk_biofuels_for_publication.pdf

[40] https://www.ufop.de/files/7715/3355/6618/Sustainability-10-02455_DBFZ.pdf

[41] http://futurefuelstrategies.com/wp-content/uploads/2018/05/Update-on-the-REDII.pdf

R&D RECOMMENDATIONS

- Biofuel sustainability should be embedded in broader efforts towards sustainable use of biomass and land, and the development of innovative land and biomass management strategies is worth pursuing, particularly for food crops.
- Define and tailor sustainability criteria for resource efficient biomass mobilisation practices; per feedstock type and per ecological zone depending on the agro-climatic conditions
- Relevant, transparent and science-based data, tools and common standardised LCAs for practical implementation of sustainability requirements in the legislation and market place should be further developed.
- 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
  - based as much as possible on data from demonstration or industrial-scale projects
  - for EU relevant geographies, for both domestic and imported feedstocks or biofuels
  - for the three dimensions of sustainability (environmental, social and economic)

- Models, monitoring and impact assessment tools to
  - help assess implementation of enacted legislation,
  - prepare public (policy) and private (investment) decisions,
  - better assess the issues around direct and indirect land use change
  - help manage the issues of competing uses of arable land and biomass.
  - provide satisfactory guarantee of the sustainable use of biomass while stimulating best practice

- Develop projects to demonstrate the sustainability of full value chains[42]
- Develop a few types of high-quality biocommodities out of a portfolio of biomass sources that meet standardized sustainability criteria to develop an international trading market for sustainable biomass, and thereby accelerating the deployment of the production of bioenergy and biofuels.
- Develop sustainability criteria for fuels that are derived from electricity and CO_2. How to ensure sufficient sustainability (renewable energy content) of the electricity used, and how to deal with CO_2 that is sourced from biomass, the atmosphere or from off-gas or flue gas of fossil plants (included as regulatory act for 2021).

[42] For example, the FP7 project S2Biom ((http://www.s2biom.eu/en/) developed a toolset with databases to address these questions for the sustainable delivery of non-food biomass for the bioeconomy.

5 BIOMASS AVAILABILITY AND SUPPLY

MAIN RECENT DEVELOPMENTS AND FACTS

The issue of mobilising biomass feedstocks in a sustainable and resource efficient manner[43] remains vital for Europe; firstly, to meet the targets in the Renewable Energy Directive (RED)[44] and the upcoming RED II for a low carbon energy system beyond 2020 and secondly, to foster in the same time the sustainable development of the European bio based economy and meet the objectives of the Bio-Based Industries (BBI) Joint Undertaking[45] to contribute to a more resource efficient and sustainable low-carbon economy and to increasing economic growth and employment, in particular in rural areas, by developing sustainable and competitive bio-based industries in Europe, based on advanced biorefineries that source their biomass sustainably. The Infobox 3 describes this in more details.

Currently, biofuels are mainly produced from agricultural biomass, mostly oil and starch or sugar crops. However, industry is continuously exploiting improved sustainability practices to ensure they source raw materials that meet the sustainability criteria set and also expand feedstock types and diversify their biomass portfolios to residues by-products from agriculture, forestry etc. and lignocellulosic biomass from residuals, perennial grasses and short rotation tree species.

In contrast to other biomass-based renewable energy carriers, the production of biomethane or biogas as a renewable fuel is not aligned to one feedstock, but usually demands a substrate mix, thus unlocking a very significant biomass potential[46]. Typically two to five different feedstocks are used in biogas plants.

Since the 1950s microalgae have been grown commercially, to produce fish food, human food additives and pigments, in ponds or closed photo-bioreactors. It has been estimated that micro-algae could produce several times more oil than the oil palm, the most productive terrestrial oil plant. Most scientific references suggest an oil production potential of 25-30 tons per hectare and year. However, a recent report suggests that large scale microalgal lipid production is not yet economical viable and the energy needed for microalgal biomass production for biodiesel can be six times of the energy produced in the microalgal biodiesel[47,48,49,50].

In the past 13 years the seaweed harvest has grown by 129%. The seaweed cultivation in Europe is still at small scale, and used for alginate production, human consumption, fertilizers and in medical applications. For biofuel applications, high carbohydrate containing (brown) seaweed species are the most relevant as they can yield a biomass containing 10-15 tons carbohydrates per hectare[51,52].

Both micro-algae and macro-algae are considered as a potential feedstock for biofuel production in the overall biorefinery concept.

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43 According to the EU 2020 Flagship Initiative Resource efficiency is a way to deliver more with less (natural resources). It increases aggregate economic value through more productive use of resources over their life cycle. It requires using those resources in a sustainable way, within the planet's long-term boundaries. This includes minimizing impacts of one resource's use on other natural resources.

44 Directive 2009/28/EC of the European Parliament and of the Council of 5 June 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.

45 http://www.bbi-europe.eu/about/objectives#sthash.pYSyVXdt.dpuf

46 A recent study from NGVA and EBA sees a potential of 189 TWh biomethane by 2030; 19 bn m³; g-mobility: Driving Circular Economy in Transport, 2018; https://www.ngva.eu/medias/g-mobility-document/

47 IEA Bioenergy Task 37 report: A perspective on algal biogas, published September, 2015

48 P. Thangavel and G. Sridevi (eds.) (2015), Environmental Sustainability, 129 DOI 10.1007/978-81-322-2056-5_8

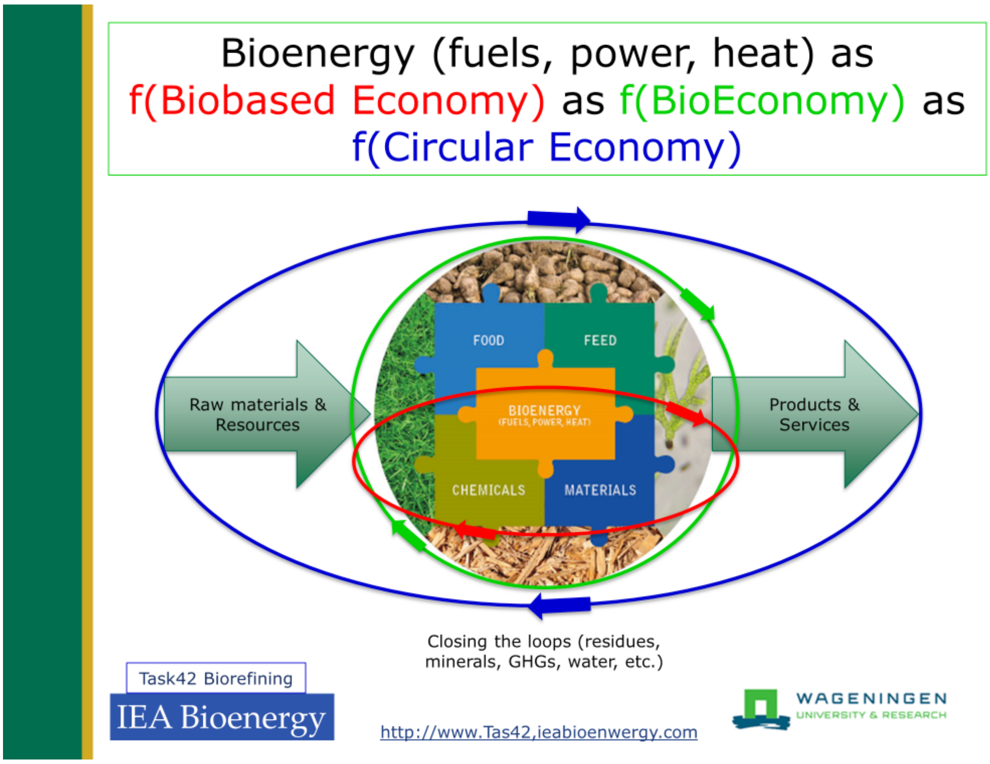
49 http://documents.worldbank.org/curated/en/947831469090666344/pdf/107147-WP-REVISED-Seaweed-Aquaculture-Web.pdf50

50 Bosch, R., M. van d Pol & J. Philp. 2015. Define biomass sustainability. Nature 523:526–527.

51 http://documents.worldbank.org/curated/en/947831469090666344/pdf/107147-WP-REVISED-Seaweed-Aquaculture-Web.pdf

52 Bosch, R., M. van d Pol & J. Philp. 2015. Define biomass sustainability. Nature 523:526–527.

Infobox 3: Biofuels in the current and future Circular Economy



Bioenergy, including biofuels, will play an important role in the current and Future Circular Economy

Figure 4: Bioenergy incl. biofuels within the Circular Economy [Wageningen University & Research, IEA Bioenergy Task42]

In the **short-term**, bioenergy (fuels, power, heat) in parallel to more established use of agricultural and forest biomass has and will continue to play an initiating role in the transition to a Circular Biobased Economy (the sustainable use of biomass for non-food applications) and a Circular BioEconomy (the sustainable use of biomass for both food and non-food applications). The bioenergy sector – as frontrunner for sustainable biomass use for non-food applications – provides expertise on sustainable biomass sourcing and certification, existing and running facilities, infrastructure and full biomass-to-products value chain based stakeholder consortia that potentially can be used to kick-start large-scale biorefinery deployment with the overall goal to increasingly use available biomass sources in a sustainable way to efficiently co-produce food/feed ingredients, chemicals, materials, fuels, power and heat/cold in a synergistic way.
In the **mid and longer-term** bioenergy is expected to play a significant role as part of the decarbonisation of the transport sector, and in efficient biocascading/biorefining approaches within the Circular BioEconomy by:

- Providing sustainable biofuels – biofuels sustainably produced from non-food biomass sources – to market sectors where they are the only alternative fuels to reduce their GHG-emissions, i.e. heavy duty road transport, aviation and maritime shipping (**biofuel-based biorefineries**).
- Conversion of biorefinery process residues, and other agro, forestry and post-consumer residues, to both power and heat to be used to meet the internal energy requirements of **product-based biorefineries** and/or for external use, for example to meet (part of) the logistical energy requirements for biomass sourcing and product delivery purposes.

Flexible market following **integrated food/non-food biorefineries**. These biorefineries will produce products for the food and/or the non-food markets, incl. bioenergy/biofuels, more or less guaranteeing a certain bottom price for the biomass providers.

Theoretical calculations show attractive potential for future algae-based biofuels, with high productivity per unit land area, but cost reduction and scale-up are critical challenges.
Europe is forecast to import 80 million tons of solid biomass per year by 2020.

Key challenges for sustainable biomass supply towards 2030 can be summarised as follows:

- **Sustainable biomass sourcing incl. aspects as: biomass technical, economic and sustainable sourcing potentials; storage & logistics; combining decentral production of high-quality biocommodities (intermediates) for more central production of advanced biofuels/bioenergy**
- **Broadening the amount of sustainable biomass available to the industry by increased and improved recovery, by broadening the spectrum of biomass feedstocks used for biofuels and by reducing biomass costs at the plant gate: Europe offers a diverse portfolio of feedstocks that are produced as primary or secondary products from agriculture, forestry and waste sectors.**
- Develop a few types of high-quality biocommodities out of a portfolio of biomass sources that meet standardized sustainability criteria to develop an international trading market for sustainable biomass, and thereby accelerating the deployment of the production of bioenergy and biofuels.
- 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.
- **Informing policy formation and updates at European, national, regional and local level:** resource efficient and sustainable biomass supply remains an important issue both for achieving the policy and respective targets across different sectors (energy, fuels, biomaterials, etc.) and governance levels in Europe but also for attracting new investments in biorefineries and the biobased economy. Current policies place focus on feedstocks that are already on the market leading to strong competition in terms of land, water and food/feed. Mobilising the unused potential from residuals and waste streams alongside sustainable cropped biomass options requires thorough technical knowledge and long term policy steering to make the investments and changes in management possible.

POLICY RECOMMENDATIONS

Based on the above-mentioned considerations, future policy and implementation strategies should strengthen complementarities and synergies among different sectors using arable land and/or biomass, as foreseen in the RED II regulation and its upcoming delegated acts.

- Recognise low ILUC practices at a crop system level.
- Create a level playing field for biomass resources regardless to their end markets, and without undue transfer costs.
- Ensure that biomass production and sustainable land use management strategies (including marginal land) is well integrated in the Common Agricultural Policy beyond 2020.
- Ensure that the RED II stipulations on low-ILUC practices and feedstocks are “fit for purpose” in European agriculture.
- Support for establishing cooperatives/ clusters to help mobilize potentials from small and fragmented land parcels.
- Place focus on marginal land opportunities and steer biomass production systems.
- Promote education and training to meet the future demands in upstream operation.

R&D RECOMMENDATIONS

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 and resource efficiency 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 use of biomass should be addressed in a coherent effort shared with the relevant stakeholders and initiatives. Some strategies are in contradiction, however, such as breeding efforts for the past decade were dedicated to increase the corn/straw ratio of cereals and now it is proposed to increase the straw yield.

I - Broadening the spectrum of biomass feedstocks and reducing biomass costs

a) Sustainable feedstock production

- Improving crop yields, traits and availability to meet the growing demand of multiple sectors.
- Cropping systems suitable to marginal, low quality, abandoned lands in Europe, including dry farming in water scarce conditions.
- Ecological intensification of agriculture/ forest – matching feedstock production to the ecological and climatic zones, optimising and recycling nutrients and water, new pest and disease control techniques.
- Multifunctional agro-forestry - combining agricultural and forestry best practices to create diverse, productive, profitable, healthy and sustainable land-use system.
- Cost efficient algal biomass production on a larger scale. Optimisation of algal strains, that does not only refer to yield rates, but also to tolerance of contaminants, chemical composition, fouling etc.

b) Harvesting; Collection; Storage- maintain a system perspective within the value chains

- Improve collection, sorting and handling of various by-products, residues and waste streams.
- Develop harvesting and collection systems (new equipment, new chains) to maximise supply by minimizing costs per unit.
- Assessment of potential, collection, logistics, economics and environmental impact of crop residues, forestry, wood and wood-processing residues, and food-processing residues.
- More efficient and automatized harvesting systems for micro- and macro-algae storage and stabilisation
- Develop feedstock quality and monitoring systems both for wet and for dry storage.
- Develop primary refinery technologies that can be applied at local level to sustainably pre-process biomass sources into high-quality and high-density biocommodities for efficient long-distance transport and use in more central secondary refineries for the co-production of bioenergy/biofuels and biobased products.
- Increase the efficiency of logistics over longer distances in the future by developing and testing technology and supply chains.
- Improve the process of collection hubs by assessing legal prerequisites, optimal technology and location for specific biorefinery cases.
- Integrate biomass value chains with other value chains (e.g. integrated harvesting of residues & the main product(s), new alternatives for backhauling, multiple-use machines to alleviate seasonal fluctuation

II - Informing policy formation and updates at European, national, regional and local level

a) Value chain analysis

- Analysis and estimation of direct and indirect impacts over employment and economy at regional and national scale from specific value chains and the use/promotion of biofuels
- Optimise supply tools taking into account various land use, resource efficiency, displacement effects, market interdependencies, etc.
- Demonstration of a portfolio of value chains (subject to regional ecology and climate) with high potential for feedstock supply in relation to availability, infrastructure and supportive policy framework.
- Supply and demand analysis and impacts for policy and financing mechanisms (local, regional level).
- Best practices, mobilisation, benchmarking

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

KEY ISSUES AFFECTING BIOMASS MOBILISATION BY 2020 AND 2030

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

- The ILUC application and the development of low ILUC cultivation methods
- Increase biomass availability and broaden biomass feedstock types
- Reduce biomass costs through improved practices for harvesting, collection, handling and overall logistics
- Evaluate and identify best algal cultivation, harvesting and processing technologies to use it for bioenergy/ biorefinery production for both microalgae and macroalgae
- Evidence based information for policy at European, national, regional and local level
- Improve knowledge and increase awareness among biomass producers and European regions
- New concepts are under development that allow for smaller scale production units that only need biomass catchment areas of around 50 km radius to supply only around 30,000 tons of dry biomass per year. This will ease the procurement of sustainable biomass.
- Several countries in the Southeast and East of Europe, which are seen as potential large biomass producers, have not yet discovered the potential they hold.

R&D RECOMMENDATIONS

- Increase biomass yields over the time and availability (reduce the total amount of land conversion) to meet the growing demand of multiple sectors.
- Adapt agricultural and forestry practices to ensure low GHG emissions from crops and feedstock cultivation.
- Improve forest breeding and forest management to increase the sustainable biomass supply.
- Develop appropriate logistics to ensure year-round supply for biorefineries; including research on transportation and storage issues.
- Integrate biomass value chains with other value chains (e.g. integrated harvesting of residues & the main product(s), new alternatives for backhauling, multiple-use machines to alleviate seasonal fluctuations).
- Use enabling technologies (digitalization, big data, sensor technology) for resource management (including big data and automation for optimal harvesting, storage, etc.).
- Developing technologies to access difficult terrains, e.g. steep slopes
- Develop other forms of low-ILUC practices.

POLICY RECOMMENDATIONS

- Support resource efficient supply following a system approach (including legal and financial mechanisms and measures).
- Transparent and common requirements on biomass production.
- Place sustainability, smart and efficient use of resources at the heart of industrial, business and social activities.
- Develop sustainable use strategies including marginal land under given climatic conditions.
- Facilitate indigenous supply but with balanced approach and with respect to World Trade Organization (WTO) and international trade procedures.

MARKETS & INDUSTRY RECOMMENDATIONS

- Assess "cross-sector" resource availability at regional level with guidelines for resource efficiency and competition
- Identify "hot spots" of bioenergy and biobased materials. Assess the regional balance of biomass supply with respective demand. The idea would be to match biomass potentials with the best local solution
- Southeast and East European countries have to be encouraged to cultivate, harvest and sell biomass, storage and trading points have to be established, etc. It will be important not only to encourage them to set up biomass value chains but to also provide guidance on how to set up value chains that fulfil the sustainability criteria.
- Ensure win-win situations for all partners along the value chain.

6 CONVERSION PROCESSES[53]

MAIN RECENT DEVELOPMENTS AND OUTLOOK

The key objectives for biofuel conversion technologies were already highlighted in the 2008 SRA/SDD: Developing energy- and carbon efficient biomass-to-fuel processes aiming at decarbonisation of the transport sector which are flexible with regard to feedstocks and produce high-quality, sustainable, biofuel end products.

The RED[54] target defined in 2009 was 10% of renewable energy in transport in 2020. The latest statistics for 2016[55] indicate that 7.1% has been accomplished, including use of RE power and double-counting for certain fuels and projections are that the target will be met in 2020. The use of biofuels in 2016 was 13.8 Mtoe54[55]. Diesel-type biofuels constituted 80%, gasoline-type 19% and bio-methane 1% of the consumption. The main use of biofuels was in low-blends into fossil diesel and gasoline, and to a lower degree used neat or in high-blends.

Biofuels such as ethanol, or fatty acid methyl ester (FAME) and hydrotreated vegetable oil (HVO) based on crop-based feedstock intermediates such as sugar, starch or vegetable oils have been produced at an industrial level for years and are often denominated as “conventional” or “first generation” biofuels. These fuels constitute predominantly the biofuels used in the EU in 2016, 6.5 11.8 Mm^3 and 2.4 million Mm^3, respectively[56]. From a peak in 2014 with 60 installations and a capacity of 8.6 Mm^3 the numbers of conventional ethanol production plants have decreased to 55 with nameplate capacity of just over 8 Mm^3. The number of FAME plants also decreased , from over 250 in 2010 to around 200 in 2016, while the production capacity has decreased from 25 Mm^3 to 21 Mm^3 in 2016. Nevertheless, the comparison between installed capacity and the consumption indicates a relatively low capacity usage, which is worsened by imports, especially for FAME. Hydro-treatment capacity of vegetable and other oils and fats has increased rapidly during the last years to reach some 5 million tonnes per year globally in 2016, of which more than half is in the EU. In 2018, there will be 6 dedicated HVO plants in the EU and some 10 refinery co-processing installations[57] with a total nameplate capacity of just below 5 Mm^3, of which almost 4 Mm^3 in dedicated installations.

However, there remain challenges related to the sustainability of some of the feedstocks as described in the “ILUC directive[58]” that limits oil, sugar and starch based biofuels (for producing ethanol, FAME and HVO) to 7% (equivalent to 18 Mtoe in magnitude) but had a voluntary target of advanced biofuels to 0.5% by 2020 in Europe.

The RED II advanced biofuel target requires the use of such fuels of the order of magnitude of 8 Mtoe/a, while the overall targets corresponds to 35 Mtoe/a in magnitude. However the various caps, weight factors and the associated production capacity will reduce these absolute volumes considerably (possibly as low as 4 Mtoe and 28 Mtoe, respectively) in the EU or elsewhere. In addition, in order to comply with the RED II GHG reduction level in 2021, new installations should at least reach a GHG reduction of 65% compared to the fossil reference

[53] Although the ETIP Bioenergy value chain also includes the use of biomass fuels to produce electricity and heat, these conversion processes overlaps with the Renewable Heat and Cooling Energy Technology and Innovation Platform activities, and by common decisiosn such conversion technologies will be covered in a similar document by RHC ETIP

[54] Directive 2009/28/EC

[55] Eurostat

[56] EU Biofuels Annual 2018. USDA Foreign Agricultural Services. GAIN Report Number: NL8027. 7/3/2018

[57] The actual use for co-processing in e.g. 8 refineries in Spain and Portugal depends

[58] Directive 2015/1513/EU: https://eur-lex.europa.eu/legal-content/DE/TXT/?uri=celex%3A32015L1513

defined in the EU directive. Since most biofuels plant capacities are in the range of 0.05 - 0.4 Mtoe, the targets above correspond to several tens of new advanced biofuel plants.

The advanced biofuel alternatives are also expected to offer a high GHG emission reduction, enlarged biomass feedstock base, higher efficiency utilisation of the feedstocks, and minimized overall costs. Since some member state biofuel schemes are based on GHG emission reduction obligations, biofuels with even higher GHG emission reduction than the minimum level of 65% will have a higher value on the market.

To be able to contribute sufficiently to the EU 2030 biofuel targets, short-term, more advanced biofuel technologies need to be further developed and demonstrated in several dedicated value chains in various part of Europe. This is essential to have the technology basis for the roll-out of the large-scale production capacity of advanced biofuels needed in the coming decade to fulfil the sustainable biofuels and decarbonisation targets in 2030.

However, biofuels cannot compete head to head with fossil fuels even if the cost of the latter increases significantly from the lowest level in 2015. The main cost drivers are typically the feedstock cost and conversion efficiency and the capital related costs. Even if technology development, innovation, learning, economy of scale etc. will reduce the production cost over time, this probably affects capital related costs more than the other cost drivers. The feedstock cost at the plant gate may even increase from more competition and higher logistic cost when the overall use of biomass feedstock in society increases. Therefore, long term (> 10 years) relevant incentives are necessary for the introduction of biofuel technologies and build-up of capacity of biofuels on the market. Such incentives should target the early stage market introduction of technologies (TRL7, TRL8[59]) to both buy-down the technology risks, but also to reasonably secure revenues. Furthermore, building up the production capacity to a more widespread deployment (i.e. to go from TRL8 to TRL9[60]) of biofuels production also requires mechanisms to both stimulate the market up-take of such quantities and to provide more secure revenue streams on a longer term in view of the cost of the fossil fuel competitor. In addition to this business plan type of estimate, biofuel plants can provide other by-products that in a bio-based society should be more valued (biofuel-based biorefining approach, see also infobox 3), and other societal system services (such as grid balancing, access to a clean, concentrated CO_2 stream for CCS, socio-economic benefits, export of goods and services etc.) that are not yet fully capitalized. In particular BECC represents a very important benefit in view of the CO_2 budget associated with the Paris agreement goals.
So far the production of advanced biofuels in the EU has been limited to bio-methane via upgrading of biogas in a number of smaller (<0.01 Mtoe) facilities, or from one plant for gasification to biomethane and one industrial scale cellulosic ethanol plant. However, both these latter types of advanced biofuel plants are idling at present due to economic difficulties, a situation which is similar for two of the six cellulosic ethanol plants at industrial scale that have been built outside of Europe in recent years.

As was noted above, all the other ten flagship biofuel projects and two intermediate bio-oil projects awarded as part of the NER 300 program have not reached construction phase. One cause for this delay in capacity build-up is the drop in the energy prices in 2014. Another reason is that the support to large and costly biofuel projects in the NER300 projects has not been efficient in reducing the risks. Furthermore, the debate on ILUC and the shorter time horizon of policy actions relative to the capital recovery period for advanced biofuel plants have contributed to weaken investors' confidence. Outside the EU, in the last couple of years the Enerkem gasification plant in Canada is the only project that has come into operation while other projects in the USA are also delayed,

[59] Demonstration plants are considered the last non-economic step to demonstrate the performance and technical reliability of a complete conversion concept in a value chain so that the first-of-a-kind, commercial-scale industrial unit can be designed with sufficient confidence for the investment (TRL 6-7). Flagship plants are the first-of-a-kind, commercial-scale industrial demonstration units aiming at validating operational sustainability and financial viability of a complete conversion concept defined by one of the value chains (TRL 8).

[60] Actual system proven in operational environment (TRL 9)

but the ground-breaking of two installations, Red Rock Biofuels and Fulcrum Sierra Bioenergy, have been announced in 2018.

Regarding the production of intermediates by thermochemical pathways, two industrial scale plants have been established in the Netherlands and Finland, but the pyrolysis oil is mainly used directly as a fuel without any further upgrading. Regarding solid biofuel intermediates (pellets etc.) the global production capacity has grown for over a decade and reached 28 million tonnes in 2015. However, since 2015 the growth has declined due to the drop in the energy prices and delay in retrofitting projects. For 2018 the industry again projects an increase in demand.

In the 2016 SRIA, it was noted that the EU's technology leadership in this area was increasingly being challenged as more plants were built in America and that even European companies were investing in the USA and in Brazil because of their regulatory stability and the existence of financial incentives. Since then, the outlook in the USA has become more unclear as the Renewable Fuel Standard (RFS2) system[61] will be phased out in 2022 and some debate, analogous to the current RED II debate in the EU, can be expected before the policy is defined. However, more affirmative actions in developing biofuels are present in Brazil, China and India so that more competition for technology leadership can be expected to come from these countries.

If the EU wants to retain its position as the global leader in this field, all available policy instruments should be used to establish long-term policies (preferably giving clear indications also beyond 2030), in order to fulfil the RED II targets and the SET plan implementation in this field. For development and demonstration, EU FP9 "Horizon Europe") and the Innovation Fund facility of the ETS phase 4 etc. are important, but other means to stimulate commercial developments and investments, secure financing and to stabilize revenues, suitable long-term policies within the EU and member states, alone or in joint constellations, are necessary as well.

Nevertheless, and based on the Paris agreement and expectations on the RED II, some new industrial developments at TRL8-9 have been announced while other technologies have advanced or have concrete plans to advance to TRL6-7 in the near future, at higher TRL. These are for example plans for cellulosic ethanol installations in Hungary and Romania by Clariant and in Norway by St1/Norske Skog, a pyrolysis plant by Metsä in Sweden, two gasification plants in early planning in the Netherlands and Spain, respectively using the Enerkem technology, and at lower TRL e.g. Silva Green Fuels HTL plant in Norway and for lignin upgrading by Renfuel/Rottneros/Preem in Sweden[62].

In view of the variety of feedstocks with different availability and characteristics and the connection of many feedstocks' and products to existing industrial ecosystems, it is not possible to identify overall a few "best" technologies. Instead, this calls for innovative technical approaches.

Even if individual plants will be designed of a more or less limited range of design specification fuels, technologies should be developed to have a reasonable feedstock flexibility to accept the range of feedstocks expected in a variety of locations throughout Europe and elsewhere (this could be partly solved by producing high-quality widely applicable biocommodities out of them).

Furthermore, one important opportunity to reduce the cost of advanced biofuels is to integrate production to existing industries in food, forest, oil and energy industries. It is natural for example to integrate biomass conversion to industries, where biomass residues are available. Examples of such industries are power, forest, food, and pulp and paper industries. This is often NOT the best choice from an economic point of view. Local upgrading and high-efficient transport to an efficient secondary biorefinery facility might be a much more cost-effective alternative.
Similarly, it can be advantageous to integrate final fuel production from a number of decentralized facilities producing a well-defined intermediate from more disperse biomass sources into mineral

[61] https://www.epa.gov/renewable-fuel-standard-program

[62] ETIP Bioenergy has in cooperation with IEA Bioenergy a biorefinery database (http://www.etipbioenergy.eu/databases/production-facilities) where existing and planned biofuel installations are listed.

oil or bio-refineries, where for example final upgrading may be carried out at large scale. In such cases drop-in biofuels may be produced in a cost-efficient way and with a low carbon and environmental conversion foot print for the biogenic fraction of the fuels produced. This requires most conducive policy measures that allow e.g. co-processing and establish mass-balancing as the chain-of-custody approach[63] to exploit synergies derived from integration. The RED II states that the EC will provide such a regulation prior to 2021.

There are several conversion routes to produce current and advanced biofuels as biofuel components or drop-in biofuels blended in traditional fossil transportation fuels. In the "value chain dedicated tool box[64]" of technologies for biomass conversion into biofuels, and in addition to the thermochemical (gasification, pyrolysis) and biochemical (anaerobic digestion, fermentation) pathways that have reached furthest in development, new technologies and approaches using both chemical, biochemical and thermochemical processes are in development.
They target one or more of the following aspects; biofuel production system using cheaper feedstocks, improved technical properties of the intermediates in view of their upgrading or the further conversion of biofuel products to established fuel qualities (e.g. conversion of ethanol or other higher alcohols to biojet).

The forecasts for the electricity sector in the EU indicate that there may be overproduction in certain market areas of the EU with a high share of renewable power generation. Renewable electricity with a very low carbon footprint can be seen as a valuable feed to combine with CO_2 from renewable or fossil sources for the production of renewable fuels[65] with a low GHG footprint, so called electrofuels.

In addition, the use of hydrogen obtained by use of RE power as a co-feed is advantageous in many biofuel production processes. The hydrogen is efficiently used to produce more biofuel at lower cost than for electrofuels, while the yield of biogenic carbon into biofuels is increased drastically such that the biomass resources are more efficiently used.

R&D SITUATION AND RECOMMENDATIONS

Research and development activities follow any value chain from laboratory trials to into extended commercial use, although the nature of the R&D changes from ground-breaking and novel concepts to performance improvements and product development.

For each value chain, see Annex 1 and 2, the number of R&D topics can be made very long and detailed, but for the purpose of this document, the infoboxes below illustrate one or a few key R&D challenges for the technology pathway in question.

Regarding conventional biofuels, subject of the 7% post-2020, cap level, research and improvements in the value chains 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 to meet the new 65% reduction limit, energy balances, water balance and management as well as material inputs. This will be addressed by on-going product developments associated with a mature industry in the areas of residue and other oils

[63] Chain-of-custody approaches include
- Identity preserved: All certified products originate from identifiable sources. No mixing with other fuels, certified or not certified, allowed;
- Physical segregation: Only certified products are delivered. The product flow is segregated from other products but can be mixed with other certified products;
- Mass balance: Administrative monitoring of the trade of. Mixing products in the supply chain is allowed provided that overall company quantities are controlled to match specific inputs and outputs;
- Book-and-claim: Consists in tradable certificates, or similar, that are associated with certain fuel batches. Once the physical fuel batch is sold, the traceability link between the physical product and sustainability characteristics is lost. This method can be combined with any of the above based on how certificates are awarded.

[64] Seven value chains from biomass feedstocks to products and intermediates have been defined; thermal gasification to liquid fuels and bio-methane, conversion to power and heat at high efficiency, biochemical conversion to liquids and gases, physical, chemical and thermochemical conversion to intermediates for direct use or further upgrading, production of aquatic biomass feedstocks.

[65] Renewable fuels can also be based on electricity only as the energy containing feedstock and are then called electrofuels. This process chain is based on electrolysis (production of hydrogen) and a subsequent chemical/biological synthesis to produce a gaseous (e.g. Synthetic Natural Gas) or liquid fuel (e.g. methanol, Fischer-Tropsch-Diesel).

and fat pre-treatment, conversion process intensification etc., respectively improvements in enzymes and yeast strains, novel separation techniques etc. as well as an increased use of anaerobic digestion, CHP and biomass fuels. By-products such as glycerine and DDGS are already important in ethanol plants solids are increasingly separated from the broth prior to fermentation and are utilized to produce by-products and biogas that in the latter case also improves the GHG footprint of the plant. The so-called 1.5 G technologies that are being introduced in the USA could be yet another such improvement. These technologies use enzymes and technologies to convert part of the corn kernel fibres in 1 G ethanol plants to fermentable sugars such that cellulosic ethanol is produced at a rate of up to 10% in relation to the 1 G plant nominal output, but also the corn oil output increases. However, different views between USA and the EU on the acceptability of the DDGS if GM microorganisms are used to ferment the pentose sugars is a restraining factor for use in the EU as only the hexose part would contribute to the yield increase.

For technologies based on hydrotreatment of oils and fats, the sourcing and pre-treatment of sustainable feedstocks are one main issue to allow the full use and expansion of these technologies. In the case of HVO (hydrotreated vegetable oils), one specific advantage is the drop-in character of the fuel products and here developments to increase the yield of bio-jet is of specific interest.
Conventional (1st generation) biofuel plants use food-based biomass as resources. A potential interesting approach could be to analyze if these plants can be operated in more flexible modes, producing either biofuels or food ingredients, depending on certain market conditions. I.e. in case of an overload of raw materials the price for farmers would go down at a constant food market request; however, if part of the raw materials could be converted to biofuels, the farmers income could be kept constant, etc.).

Regarding the advanced biofuels, several value chains need to be developed, demonstrated and deployed. The foremost priority is to establish more mature value chains as industrial realities and have a volume build-up on the market of such biofuels.

In addition, research priorities for less mature concepts will be focused on the concept and process development in specific value chains and proceeding from innovative laboratory pilots to industrial demonstration, and subsequent commercialisation. Cost-efficient production of advanced biofuels requires energy- and carbon-efficiency. Furthermore, feedstock flexibility/adaption for these developing technologies is another key aspect to allow production to be based on a wide range of feedstocks representing various European (and non-European) regions, even if each individual plant is designed for a more limited span in feedstock properties. Another approach to feedstock flexibility is to use smaller-scale decentralized and sustainable production of more energy dense and well-defined high-quality intermediates (pellets, pyrolysis oil, lignin etc.) to exploit disperse feedstock sources of different characteristics, and then do the final conversion of the intermediates in a large scale,

Infobox 4: Conventional biofuels conversion priority R&D&D topics

Ethanol

- develop and demonstrate strategies for the decrease of energy use and CHP footprint (novel separation methods, by-products, production of biogas, bio-CHP, etc.)
- 1.5 G cellulosic ethanol technology demonstration and implementation

Bio-diesel

- sourcing of sustainable feedstocks
- develop improved pre-treatment of unconventional feedstocks (UCOME, high-FFA feeds)
- develop improved reaction conditions (novel catalysts, enzymatic catalysis, etc.)

HVO

- Sourcing of sustainable feedstocks
- Demonstrate improved yield of bio-jet

All: analyse the opportunities to convert single biofuel facilities to more flexible facilities producing biofuels and/or food/feed ingredients depending on changing market conditions secondary biorefining facility, gasification plant or fossil power plant, refinery etc. For most of these intermediates but also for conversion of sugars and alcohols to hydrocarbons like the HVO processing, hydrotreatment is a key technology to upgrade such intermediates to reach drop-in fuel products.

Conversion technologies to distillates (diesel+jet), deserve priority attention because of increasing demand especially from heavy duty road transport as well as air and marine transportation, while such fuels are also (required to be) compatible with the existing infrastructure. This is in particularly important for aviation fuels. In addition to drop-in fuels, oxygenates such as methanol and DME can play an important role as an alternative fuel in this segment. It should be noted that the use of biofuels is typically associated with better engine performance and reduced levels of regulated tail-pipe emissions.

Value chains which make use of synergies with existing raw materials logistics and industrial facilities offer the best economic and industrial framework to manage the high risk/high cost of deploying promising new technologies, and which can thus help the transition from conventional to advanced biofuels. Another approach to exploit synergies is biorefineries that convert biomass into fuel, chemicals and material products in parallel.

In addition, there are many pathways where there is also an opportunity to exploit the potential for high-value co-products and by-products. In particular, in the area of algae-based production, the low fossil prices have significantly shifted attention from fuels to high-value nutritional, cosmetic or other products. There are also examples from other pathways. Bio-char from thermal processing is promoted by some developers as a by-product where the market value could be higher than the energy value. Also, the extraction of aromatics from gasification processes could provide bio-based chemicals into an overwhelmingly fossil product line. For lignocellulosic ethanol plants, developments look at the significant mass of lignin residue that today is mainly used as fuel in such plants. There are also other lignin-based developments using lignin extracted for pulp industry cooking liquors. Summarised, using biorefinery approaches are key for the production of advanced biofuels in a sustainable way; either by using biofuel-based biorefineries where the production of biofuels is the main goal and bioproduct-based biorefineries where the production of biobased chemicals/materials is the main goal co-producing process residues (lignin etc.) that can be used for the production of advanced biofuels/bioenergy (see infobox 4).

Technologies at commercial, early industrial or demonstration stage (TRL6-9), and therefore must be the main contributors to the target for advanced biofuels in 2030, are gasification, pyrolysis, biochemical conversion to ethanol and other alcohols and anaerobic digestion. In some cases, such as e.g. various pyrolysis technologies, intermediate products require additional upgrading to transport fuels in stand-alone

Infobox 5: Advanced thermochemical biofuels conversion priority R&D&D topics

First and foremost, for all value chains, demonstration at industrial scale and deployment and using the biorefinery-based full biomass-to-products approach for optimised overall chain sustainability

Specific key R&D topics

Gasification:
- fuel pre-treatment for and fuel flexibility in primary conversion
- develop and demonstrate improved gas cleaning (e.g. hot gas cleaning) and upgrading
- demonstrate hybrid RE power processes

Pyrolysis:
- develop systems with improved intermediate quality (e.g. reduced O content)
- demonstrate upgrading of intermediate products (incl. co-processing)

HTL:
- fuel pre-treatment for slurrying dry feedstocks
- demonstrate process technical feasibility (materials and components) for different types of feedstocks

facilities or by co-processing in refineries but will then result in drop-in hydrocarbon products.

The need to demonstrate and deploy these technologies at an industrial scale does not mean that the R&D phase is completed. On the contrary, the experiences from the first installations and the potential for integration of R&D activities into an industrial setting raise the R&D to a new level for any technology, where improved performance mapping, new processes and incremental improvements all assist in increasing the performance and to realize cost reductions along the learning curve.

There are also technologies that are emerging from the laboratory scale into pilot plants and demonstrations, TRL5-7, that can find their first industrial application in the coming decade. Such technologies are e.g. hydrothermal conversion to solids, liquids and gases, hydropyrolysis and other forms of catalytic pyrolysis. Another set of technologies that can come into industrial use is the conversion of various biofuels and intermediates such as alcohols and sugars to hydrocarbon drop-in fuels. For such technologies, the R&D needs relate mainly to the system demonstration, to components and materials and to the product upgrading.

Technologies that enable the utilization of electricity are in the early commercialisation phase (e.g. electrolysis) or in the research and development phase (e.g. plasma-assisted conversion or gas cleaning, electro-catalytic conversion).

Electricity can generate hydrogen through electrolysis which together with a carbon source (e.g. CO_2) can react to methane or liquids; referred to as PtX[66]. Several such initiatives are in the demonstration phase. The production price primarily depends on a continuously low/negative price of electricity.

Yet another way to make use of low-cost power is to let the hydrogen produced from electrolysis be blend into synthesis gas from a biomass gasification plant. For several conversion routes energy in the hydrogen becomes product energy with an efficiency of about 90%, while the fuel generation increases between 50 and 100% compared to the case with no additional hydrogen. This is due

Infobox 6: Advanced biochemical biofuels conversion priority R&D&D topics

First and foremost, for all value chains, demonstration at industrial scale and deployment and using the biorefinery-based full biomass-to-products approach for optimised overall chain sustainability

Specific key topics

Lignocellulosic ethanol, higher alcohols, hydrocarbons:

- develop improved feedstock pre-treatment (less water, energy, chemicals and enzyme intense) to improve product titre
- develop novel strains to produce hydrocarbon or long-chain fatty alcohols from sugars
- develop and demonstrate improved separation technologies (e.g. ethanol from broth or to avoid product inhibition by continuous removal of products)
- Sustainable lignin valorisation to energy/fuels and biobased products

Syngas fermentation:

- improved understanding of strain contaminant tolerance and appropriate gas cleaning
- develop and demonstrate improved separation technologies (e.g. ethanol from broth)
- develop measures to improve conversion efficiency

Biogas

- develop and demonstrate feedstock pre-treatment to enhance gas yield and allow processing of recalcitrant materials
- develop and demonstrate improved technologies for biogas upgrading to biomethane
- improve use of digestate
- upgrade conventional biogas facilities to integrated biogas-based biorefineries efficiently co-producing biofuel precursors (fatty acids, biogas) and biobased products

[66] Power to X, X being some form of fuel or other product.

to the fact that the green carbon in the feedstock becomes carbon in the product instead of being excreted as CO_2 in order to de-oxygenate the biomass. Instead water is formed. The oxygen from the electrolyzer can then also be used in the process, saving energy in the air separation plant.
Depending of their integration with other technologies or being stand-alone grid balancing installations, the R&D activities have to be adapted to the TRL level of the main process.
There are also methods to utilize intermediate products such as ethanol and sugars to hydrocarbons, which could be of importance, in particular for bio-jet. However, there are also economic barriers for the feasibility of converting a blend-in biofuel such as alcohols to a drop-in biofuel, including that incentives and mandates have this far focused on road traffic.

The use of solid intermediates is already a large market of several tens of million tons per year. To further this industry, improved materials from both a user and logistic aspect is required, while also broadening the feedstock basis is of importance, requiring developments in the pre-treatment to remove contaminants as part of the process.

The use of algae to produce oil and sugar intermediates has attracted attention as the potential is high and not associated with food- and feed issues.

There are also developments in new technologies based on tools previously developed for other applications in the pharmaceutical, chemical, energy and forest industries which are emerging, such as synthetic

Infobox 7: Renewable fuels priority R&D&D topics

PtX:

- Demonstrate novel electrolysers with improved performance
- Develop and demonstrate reverse Water Gas Shift technology
- Develop and demonstrate direct synthesis technology to fuels

Hybrid systems

- Demonstrate novel electrolysers with improved performance
- Demonstrate hybrid advanced biofuels chains
- Develop solar heat integration in thermochemical conversion

Infobox 8: Advanced chemical biofuels conversion priority R&D&D topics

Overall, demonstration at industrial scale and deployment

Specific R&D topics

Alcohols to hydrocarbons:

- develop and demonstrate improved conversion technologies to increase the yield of, in particular, the bio-jet range of hydrocarbons
- develop and demonstrate separation technologies

Sugars to hydrocarbons:

- develop and demonstrate improved conversion technologies to increase the yield of hydrocarbons, and in particular to bio-jet
- develop and demonstrate biochemical and chemical technology integration, in particular for jet-fuel substitutes
- Lignin to hydrocarbons for either fuels, chemicals and biobased materials

Infobox 9: Advanced solid intermediates conversion priority R&D&D topics

Solid intermediates

- demonstrate torrefaction value chains at industrial scale
- improve solid intermediate properties, in particular for lower-quality feedstock by removal of feedstock impurities (alkali, chlorine), e.g. by combining torrefaction with washing
- develop torrefaction-based solid intermediate bioenergy carriers with additives to mitigate technical problems in downstream processing

biology[67], new catalytic processes and high-pressure conversion that may have a long-term application, TRL-3-5, i.e. only likely to come into industrial use post-2030. Examples are algae, hybrid RE technologies, novel biosynthetic fuel producing pathways etc. Such technology prospects are best addressed by conventional R&D measures and demonstration activities once reaching TRL5.

Furthermore, currently there is only a handful of plants in operation in Europe. To have a share of advanced biofuels of the order set by the targets by 2030, this requires some hundreds of new plants to be built in the coming decade. To realize such a build-up of capacity sets large demands on financial, material, manufacturing and human resources; which is as important as the mobilization of biomass feedstock.

Infobox 10: Advanced intermediates conversion priority R&D&D topics

Aquatic biomass production

- develop and demonstrate high productivity cultivation systems for micro- and macroalgae at low CAPEX and OPEX.
- develop and demonstrate improved methods for harvesting, drying and intermediate (oil, sugars) recovery for further processing
- demonstrate biofuels sustainability from algae through LCA assessment and positive energy efficiency at demo scale

Infobox 11: Novel concepts priority R&D topics

Bio-solar cell factories

- concept and strain development
- development of product separation techniques to circumvent product toxicity to cell factories
- validate the technology performance

Synthetic photosynthesis:

- concept and substrate development
- validate the technology performance

Microbial hydrogen generation

- concept and strain development
- demonstrate the technology performance at TRL 5-6

Technology	Lab and prototype (TRL1-5)	Demonstration (TRL6-7)	Early market development (TRL8)	Widely Deployed (TRL 9)
Transport biofuels				
Ethanol from sugar and starch crops				■
Biodiesel from oil crops				■
Biomethane for transport			■	
Cellulosic ethanol			■	
Other biological routes	■			
HVO				■
Upgraded pyrolysis oil – stand-alone plant		■		
Upgraded pyrolysis oil –			■	
co-processing with crude oil			■	
Upgraded synthesis gas		■		
Hydrothermal liquefaction	■			
Non-biomass low-carbon fuels		■		

Table 1: Bioenergy technologies: Technology readiness status[68]

[67] Synthetic biology: rational design of the metabolism of a micro-organism to produce a desired molecule using modern biotechnology tools

[68] Technology Roadmap-Delivering Sustainable Bioenergy, IEA 2017,p.29, adapted

MAIN RECENT DEVELOPMENTS

- The use of biofuels in transport in the EU reached 7.1% in 2016 (including double- and multiple counting of some fuels and RE electricity, respectively), relative to the RED target of 10%, and constituted 13.8 Mtoe. Diesel-type[69] biofuels constituted 80%, gasoline-type[70] 19% and bio-methane 1% of the consumption. Biofuels were mainly used in low-blends into fossil fuels, and to a lower degree used neat or in high-blends in dedicated or dual-fuel drive trains.
- Despite the increase in the use of biofuels in the last decade and also in electromobility, the demand for hydrocarbon-type fuels is still increasing in the heavy-duty road, air, and marine transport sectors, while their respective infrastructures limit the use of alternative fuels.
- The ILUC directive imposed a cap on the use of and crop-based biofuels (sugar- and starch-based ethanol, FAME and HVO based on virgin vegetable oils etc.) to 7% within the RED target. This has impeded the expansion of these so-called 1st generation installations while imports etc. have reduced the average capacity usage factor in existing installations.
- Production of drop-in renewable diesel for unlimited use in current diesel engine technology has been established in some European countries and elsewhere. These processes can, if designed and operated for this purpose, also provide bio-jet (HEFA) fuel. The feedstock is several types of biogenic oils and fats, e.g. vegetable oils, agro-industrial wastes and residues as well as forest industry by-products. However, some of the vegetable oil feedstocks are seen not to fulfil sustainability criteria or meet client acceptance. The sourcing of acceptable waste and by-product feedstocks is a limitation for further expansion of this value chain.
- An increasing number of pathways to bio-jet are being approved (HEFA, SPK, SIP, ATJ etc.[71]) as blending components. However, with the exception of HEFA where some very limited quantities are being produced industrially and used for commercial flights, the production via such pathways is not yet at an industrial scale.
- Several industrial units for advanced biofuels that were decided on before the energy costs dropped in 2014 have been built and started up in 2014-15, much more in America than in the EU, whose technology leadership on this topic was increasingly being challenged.
- However, post-2016, very few new plants at industrial scale have been constructed or announced. Furthermore, several of the above industrial units have become idle, mainly for non-technical reasons
- The NER300 funding for risk sharing of innovative flag ship projects has not had the expected impacts. So far only two biofuel projects have materialized in: BEST (Biochemtex) and Verbiostraw while the other ten biofuel projects and two bio-oil intermediate projects have either been cancelled or delayed.
- The production of and international trade with solid biofuel intermediates (pellets etc.) have continued to growth for over a decade and reached 28 million tonnes in 2015 but have since not changed much due to the drop in the energy prices and delay in retrofitting projects. However, the growth in the demand is forecasted to increase again from 2018 and onwards.
- There is growing interest into electrofuels, also integrated into biofuels production (power-to-gas and power-to-liquids) boosted by low price renewable electricity. There are first pilot units in operation.

[69] Predominantly FAME and HVO

[70] Predominantly ethanol but also ethanol-containing additives such as ETBE

[71] Pathways are defined by ASTM D7566 (Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons) and annexes. Pathways use conversion technologies for drop in fuels described in this section.

THE CHALLENGE

- The updated SET Plan puts very challenging targets for the specific cost, conversion efficiency and the overall installed capacity of advanced biofuels in 2030.
- Nevertheless, biofuels cannot compete head to head with fossil fuels even if the cost of the latter increases significantly from the lowest level in 2015. In addition, by-products and other societal services of biofuels are not always fully capitalized in the cost of production estimates. Long term incentives and instruments (> 10 years) are necessary for both the initial introduction of biofuel technologies to both cover the technology risks and to reasonably secure revenues, and also for the latter build-up of capacity and more widespread deployment of biofuels production technologies to both ensure sufficient market up-take and to provide more secure revenue streams over longer periods.
- A challenge to the industry is the mobilisation of large volume, low price biomass resources. When possible, logistic supply chains of specific feedstocks for large-scale biofuels industries are available. But, to mobilize more distributed feedstocks, typically also with variable characteristics, value chains should be pursued that links decentralized upgrading of such resources into energy-dense and more homogeneous intermediates (pellets, liquid biofuel intermediates etc.) to more central biofuel production co-processing facilities.
- In view of the rapid build-up of the biofuel industry to meet the targets set, attention should also be paid to the mobilization of other resources necessary; human, financial, production etc.
- To further increase the use of sustainable biofuels and to fulfil the coming policy targets in the EU, a number of processing technologies are available or under development and which are adapted to allow the use of a variety of potential sustainable feedstocks of different characteristics to provide biofuel products.
- The challenge to meet the RED II and the SET Plan targets, respectively, is to set the conditions to proceed with the available and more developed (higher TRL) advanced biofuel technologies into demonstrations and industrial deployment early in the next decade to achieve the build-up of capacity required by any of the targets discussed. In parallel, it is necessary to identify and implement improvements in performance and cost of these technologies, and to also pursue the development and demonstration of new, cost-efficient technologies to allow utilization of additional feedstocks later in the coming decade.

R&D RECOMMENDATIONS

- Policies and associated mechanisms to stimulate the technical development of advanced biofuels and to ensure the market up-take of such fuels, as well as to provide more secure revenue streams for producers on a longer term are needed.
- Local upgrading and high-efficient transport to an efficient secondary biorefinery facility might be a much more cost-effective alternative.
- Conversion technologies targeting fuels for heavy duty road, air, and marine transport deserve priority attention because of lack of alternatives and their still increasing demand.
- Value chains as identified originally by the European Industrial Bioenergy Initiative (EIBI), see Figure 5: Biofuels deployment leveraging on industrial synergies with existing facilities also deserve priority attention.
- The key priorities for commercial and near-commercial biofuel technologies, both conventional and advanced, are to improve economic performance (CAPEX, OPEX), increase technology feedstock flexibility and simultaneously decrease the environmental footprint of the conversion processes (GHG, energy balance, water, inputs etc.) and bring flexibility by integration with biorefineries and other industrial activities to capitalize on benefits from by-products at low cost and other societal system services (e.g. opportunities for concentrated CO_2 streams bio-CCS).
- A potential interesting approach could be to analyze if these plants can be operated in more flexible modes, producing either biofuels or food ingredients, depending on certain market conditions
- For advanced biofuels technologies (demonstrated but not yet generally commercially deployed), the focus is on:
    - Establishing demonstration plants for sustainable biofuels at both industrial scale and for decentral production of intermediates out of more local biomass resources, and further industrial replication of the demonstrated technologies.
    - This is facilitated by integration of the biofuel production, or the final conversion of intermediates, to existing industrial sites like in chemical, forest, food industry or in mineral oil refineries to reduce overall costs, or to use RE power to generate hydrogen as a supplemental feedstock.
    - Verification of feedstock flexibility of the conversion technologies to allow the processing of a wide range of sustainable feedstocks
    - Optimizations to improve energy, economy, availability and carbon efficiency of the processes used and explore the option to co-produce higher value by-products or other services.
- For advanced biofuels (not yet demonstrated), the focus is on:
    - Development, validation and demonstration of technical concepts for conversion or innovative production methods
    - Development, validation and demonstration of feedstock flexibility to process a wide range of sustainable feedstocks and of cost-, energy- and carbon efficient processes.
    - Develop and validate the upgrading of intermediates or intermediate biofuel products to biofuels in different settings.
- Developments in electrofuels should be pursued by demonstrations.
- Hybrid RE and advanced biofuels concepts should be developed and demonstrated
- Using biorefinery approaches are key for the production of advanced biofuels in a sustainable way

7 PRODUCT DISTRIBUTION AND USE

RECENT DEVELOPMENTS

Within the end-use sector the rising interest in and offering of electric vehicles in combination with the debate on biofuel sustainability have affected the attractiveness of biofuels in recent years. The "ILUC Directive" from 2015 resulted in limitations on 1st generation biofuels, but also in increased calculation factors for renewable electricity in transport (now factor of 5 for road vehicles and 2.5 for trains) when fulfilling the 2020 renewable energy target for transport. RED II provides continued multipliers of 4 for road and 1.5 for rail transport, as well as limitations on 1st generation biofuels.

Now advanced biofuels have to defend their position as one of the elements in decarbonizing transport for 2030 and beyond. Electric vehicles are entering the market, but their share in the vehicle fleet and their contribution to GHG emission reductions in 2030 will still be rather limited. Therefore it is obvious that there will be a huge need for sustainable biofuels in all sectors of transport. There are already options available where no engine modification is necessary which can substitute fossil derived diesel immediately. Others can be used in non-combustion devices like fuels cells. In 2013, the Commission launched its European alternative fuels strategy. The Communication[72] sets out a comprehensive alternative fuels strategy and the road to its implementation covering all modes of transport. It aims at establishing a long-term policy framework to guide technological development and investments in the deployment of these fuels and give confidence to consumers. The strategy states, among other things:

"For certain modes of transport, in particular long-distance road freight and aviation, limited alternatives are available. There is no single fuel solution for the future of mobility and all main alternative fuel options must be pursued, with a focus on the needs of each transport mode. A strategic approach for the Union to meet the long-term needs of all transport modes must therefore build on a comprehensive mix of alternative fuels. All options need to be included in the strategy without giving preference to any particular fuel, thereby keeping technology neutrality."

Figure 5 shows the hierarchy of fuels. Advanced biofuels are the only renewable alternative for aviation, whereas electrification is best suited for light-duty and urban vehicles. The current focus on electric vehicles might lead to a shift away from biofuel use by light road vehicles, which would make biomass available for use in aviation and other sectors dependent on liquid drop-in fuels. This should be considered in a holistic transport energy policy. Aviation fuels are highly constrained by some very critical properties such as energy content, cold flow properties and oxidation stability.

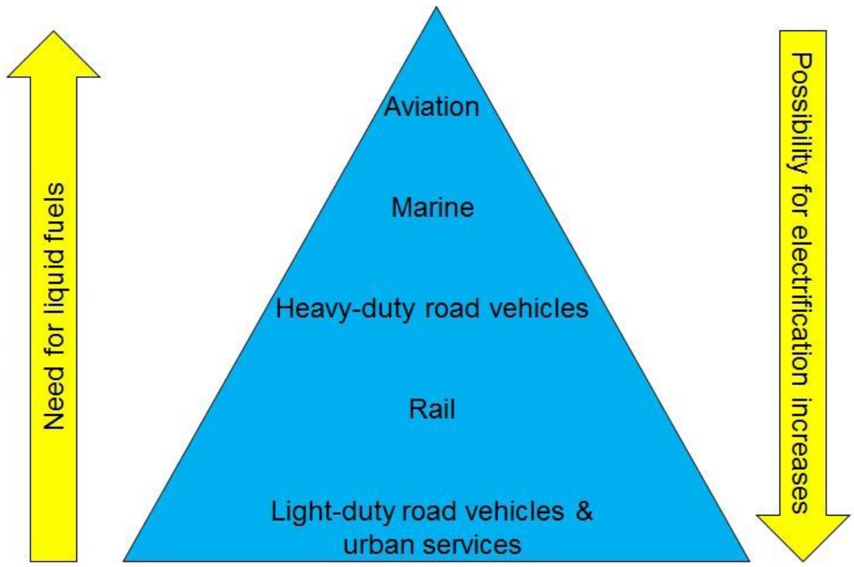


Figure 5: Hierarchy of fuels. (Ministry of Transport and Communications, Finland 2013[73])

[72] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013PC0017&from=EN

[73] https://www.lvm.fi/docs/fi/2497123_DLFE-19513.pdf (In Finnish with English abstract)

Thus, the only possibilities are drop-in -type, oxygen-free fuels. These fuels have to comply with a very strict certification procedure before being authorized in any commercial flight. Some pathways are already certified: hydrotreated vegetable oils (with a blending ratio up to 50%), BtL (up to 50%), SIP (the Total / Amyris pathway, up to 10%). Other pathways are currently in the process of development and certification. Harmonisation of standards should not be limited to Europe, but should occur globally for international transport applications such as aviation[74,75].

As a follow-up to the alternative fuels strategy, the Directive 2014/94/EU[76] on the deployment of alternative fuels infrastructure was established. The Directive focuses on gaseous fuels and charging facilities for electric vehicles. EU member states are obliged to create national implementation plans. In this process the member states should be alert to keep infrastructure for high concentration biofuels, when relevant.

DG ENER, Clima and MOVE formed a working group named Sustainable Transport Forum which had its first meeting in June 2015. The group is meant to support the Commission in the implementation of the Directive. A subgroup on biofuels was initiated at the meeting and active between 2016 and 2017.

The latest emission regulations pose some challenges to the use of alternative fuels. The Euro 6 regulation for passenger cars requires certification of flexible fuel vehicles (FFVs) at -7oC, resulting in fewer vehicle types on the market. Despite the dieselgate the European car fleet will keep a large share of diesel cars due to the past decisions in favour of this technology. The decision of the EU Parliament allows car manufactures a lead time until 2020 to lower the official NOx emission to 1,5 times the 80mg/km limit. As a result the post-Euro 6 goals are worldwide discussed, whereas China and the US consider a stricter overall NOx limit as well as a fuel- neutrality target[77].

Testing has shown that new heavy-duty Euro VI vehicles are extremely clean, diminishing the fuel effects (e.g. conventional diesel vs. paraffinic diesel and methane) on regulated emissions[78].

One of the reasons why heavy-duty Euro VI diesel engines perform so well is that real driving emission (RDE) testing is required, meaning that the emission limit values have to be met independently on how the vehicle is driven.

“Dieselgate” in 2015 has severely undermined the trust in the emission regulation and its practical application. Passenger cars certified since September 2017 have to undergo a Real Driving Emission (RDE) test to ensure that the legal emission limits are met in the field. So far consumer confidence remains limited. This is reflected by the fact that in 2016 of 21 Member States, 11 registered higher share of petrol powered new registered cars (Netherlands (79.6%), Estonia (72.1%), Malta (66.9%), Finland (66.4%), Denmark (63.1%), Cyprus (62.9%), Latvia (55.9%), Germany (53.1%), Poland (52.2%), the United Kingdom (52.2%) and Hungary (51.3%), instead of the usual, where the majority of Member States recorded much higher share of diesel powered cars. The highest share of diesel cars were recorded in Croatia (77.2%), Lithuania (71.8%), Ireland (70.3%), Spain (58.2%), Austria (57.4%), Romania (54.7%: data 2015), Belgium (52.3%), Sweden (52.2%), France (52%) and Slovenia (50.2%). The highest share by far of alternative fuels in new registrations could be seen in Poland (8.2%) and Italy (7.9%) and in Norway (16.9%). Hungary (2.5%), Liechtenstein (2.4%), Ireland and Lithuania (both 2.2%) and Germany and Sweden with a share of 2.0% of passenger cars with alternative fuels amongst the new registrations followed far behind. However, for the large majority of Member States, registrations of new passenger cars with alternative fuels made up less than 2% of the total registrations in 2016[79].

[74] http://documents.worldbank.org/curated/en/947831469090666344/pdf/107147-WP-REVISED-Seaweed-Aquaculture-Web.pdf

[75] Bosch, R., M. van d Pol & J. Philp. 2015. Define biomass sustainability. Nature 523:526–527.

[76] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32014L0094

[77] N.Hooftmann, M. Messagie, J. Van Mierlo, T.Coosemans (2018): A review oft he Europeanpassenger car regulations- Real driving emissions vr local air quality; ELSEVIER, Volum 86, April 2018

[78] https://eur-lex.europa.eu/legal-content/en/TXT/PDF/?uri=CELEX:32017R1347&rid=1

[79] http://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:F1_New_passenger_cars_with_alternative_fuel_engine,_2014-2016.png

In many cities across the EU a ban from diesel is a major discussion. Especially the renewed focus on the tailpipe emissions, NOx and particulates is supposed to support the new proposed legislation considering zero and low-emission vehicles. On the one hand this also reflects the call for accelerating the update of low emission engines and fuels. In the end it does support the electrification in cities. To move away from the diesel fuel, the road transport sector shows an increased interest in methane, CNG (compressed natural gas) and LNG (liquefied natural gas) as an alternative for the heavy duty vehicle to cover the long distance transport. Since electrification of the heavy duty sector for long distance transport does not yet seem efficient. In addition, the Euro VI regulations require the vehicles to be certified on the fuel which they are going to use. Some engines have already been certified for 100% FAME or 100% HVO. In e.g., Sweden and Finland, there is a demand for 100% biofuels in captive fleets such as buses.

New diesel dual fuel (DDF) engines using direct injection of gas (high pressure direct injection HPDI) are available. DDF engines are needed because spark-ignited gas engines cannot cater for the power and efficiency needs of the heaviest truck segment.

In order to achieve the expected CO_2 reduction, heavy duty vehicles will face CO_2 regulations whereby the light duty vehicle will expect an adjustment on the already existing CO_2 regulations. In the transport sector Lorries, buses and coaches produce around one quarter of CO_2 emissions from the road transport in the EU. The consequence is that for the heavy duty vehicles the European commission presented a legislative proposal setting the first CO_2 emission standards for heavy duty vehicle in the EU in May 2018. This proposal claims that new heavy-duty vehicles need to have 15% lower CO_2 emissions in 2025 than in 2019 and in 2030 even 30% lower CO_2 emissions compared to 2019. These targets will be reviewed in 2022. The proposed legislation also includes a mechanism to incentivise the uptake of zero- and low-emission vehicles, in a technology-neutral way[80].
Currently the appreciation of vehicle carbon dioxide (CO_2) emissions is currently based on tailpipe emissions only. Battery electric vehicles are calculated as zero emission vehicles into the manufacturer's average regulated CO_2 value.
For the light duty vehicle, e.g. cars and vans the EC proposed already in November 2017 a new legislation which contained new CO_2 emission standards in the EU for passenger cars and light duty vehicles after 2020[81]. Cars and vans accounted for 73% of road transport GHG emissions in 2015 which are responsible for around 22% of total EU CO_2 emissions[82]. The potential to reduce this amount of CO_2 emissions needs to be fully exploited. The average emissions of the EU fleet of new cars in 2030 will have to be 45% lower compared to 2021[83]. The proposal contains likewise a mechanism to incentivise the uptake of zero- and low-emission vehicles, in a technology-neutral way. The proposed legislation builds on the current regulations setting CO_2 emission standards for cars and vans which will be repealed on the 1st of January 2020[84].
The coming CO_2 regulations should help to achieve the energy efficiency targets. As complementary measures blend biofuel, blend-in, cap-and-trade biofuel mandates or CO_2 reduction fuels will come into force in some countries like Sweden for example. A well-to-tank perspective to reduce CO_2 emission from existing fuels should be included to truly understand the GHG emission impact that occurs.
It is important to realise that there should not be an adversarial set-up between electricity and biofuels or biofuels or any other energy carrier. The important thing is the need to increase the share of renewable energy in all energy carriers. It is also good

[80] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52018PC0284R(01) , https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=comnat:SWD_2018_0185_FIN

[81] COM/2017/676 https://ec.europa.eu/clima/policies/transport/vehicles_en

[82] COM/2017/676

[83] https://ec.europa.eu/clima/sites/clima/files/transport/vehicles/docs/ldv_post_2020_co2_en.pdf

[84] https://ec.europa.eu/clima/policies/transport/vehicles/proposal_en

to keep in mind that electricity is not an option for long-haul truck, ships or airplanes, so there will always be certain modes of transport calling for low-carbon liquid fuels.

Some new fuel options have appeared on the agenda, and some well-known alternatives receive renewed interest. Methanol receives interest as a fuel for captive fleets and especially as a marine fuel. Methanol can offer an energy efficient biomass-to-liquids route. The first step could be to use natural gas based methanol, which is one of the largest bulk chemicals. So-called GEM (gasoline-ethanol-methanol) fuels delivering constant heat value have also been discussed. DME research and development projects are on-going in Japan, Sweden and the U.S., but market introduction is not set yet. Electrofuels combining electricity and CO_2 to produce fuels (power-to-gas, power-to-liquids) have reached the demonstration stage.

Currently "advanced" or "second/third generation" biofuels refer to the feedstock and sustainability of biofuels. End-use performance also should be included in the criteria for advanced biofuels. From an end-use point of view, drop-in fuels would also be the preferred option in road vehicles. However, for reasons of cost effectiveness, there is also a need to incorporate higher amounts of "conventional" biocomponents into traditional fuels, especially ethanol in petrol.

Clean burning, high octane or high cetane biofuels can, in addition to delivering reduced GHG emissions, also deliver lower regulated emissions for older vehicles and energy efficiency improvements in new engines. In Finland, two companies are currently selling HVO Diesel fuel as premium quality fuel.

It is evident that the share of plug-in vehicles will increase over time. In some operational cases these vehicles will use very little fuel. For such cases fuel stability will become increasingly important. Some of the chemical reactions and interactions between fuel components leading to fuel degradation are not fully understood.

European fuels standards are constantly updated. A final EN standard for paraffinic diesel (covering hydrotreated vegetable oil as well as Fischer-Tropsch renewable diesel from solid biomass), EN 15940, was approved in May 2016. The standard for high concentration ethanol E85, EN 15293, was withdrawn. In addition, discussions to increase the ethanol content of petrol and the FAME biodiesel content of diesel fuels for captive fleets are under way. With increasingly stringent requirements for low emissions and emission stability over time, maintaining high fuel quality and low levels of contaminants becomes increasingly important. ISO and ASTM standards for DME as a diesel fuel have been approved, thus eliminating one of the obstacles for the implementation of DME.

The aviation and maritime end use sectors have different demands.

Aviation is a sub segment of transport with increasing fuel consumption and emissions in Europe and worldwide. So there

is a high demand in reducing emissions; a key instrument will be the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) approved in 2016. The aim is to allow for carbon neutral growth beyond 2020[85]. For aviation, other renewable alternatives besides biofuels will only be available at the very long term. This brings biofuels in a pole position, however technical demands are high and the willingness to pay is low. In the aviation sector, only high quality, drop-in type pure hydrocarbon fuels can be used. So far 4 technology pathways for bio-jet-fuels have been approved by ASTM, and only one of them, the hydro-processed esters and fatty acids route (HEFA), can provide commercial fuel quantities so far[86]. RED II provides a multiplier of 1.2 for biofuels in the aviation sector. Accounting under RED II and CORSIA needs to be harmonised.

The marine sector has an equally low willingness to pay for alternative fuels, but is under some environmental pressure due to the recent IMO sulphur oxide limits in emission control areas (Baltic Sea, North Sea) which will require low-sulphur fuels (0.10% m/m as of 1.1.2015) or alternatively the use of exhaust scrubbers.

For marine fuels, the most likely entry point for biofuels will be coastal or inland shipping and ferries, because of the smaller amounts of fuels required and the lower number of bunkers needed. The larger market of course is the ocean-going vessels, but it will be hard for pure biofuels to match scale. One biofuel production facility would be needed to support just one ship. Building supply chains for large amounts of marine fuels that are sold in only around 15 major bunkers are hard to imagine based on biofuels. Logistics will be really challenging. Competition of other alternative fuels is tough, e.g. LNG.

85 https://www.iata.org/about/worldwide/asia_pacific/Pages/What-is-CORSIA.aspx accessed 31 July 2018

86 http://www.irena.org/documentdownloads/publications/irena_biofuels_for_aviation_2017.pdf accessed 31 July 2018

GENERAL

- CO_2 regulation coming for HDVs and updated for existing CO_2 regulation for LDVs. In principle it is energy efficiency targets, TTW perspective and no differentiation between biofuels and fossil fuels.
- Blend Biofuel blend-in, CO_2-reduction or cap-and-trade biofuel mandates are increasingly coming into force. A WTT perspective to reduce CO_2 emission from existing fuels.
- The “Dieselgate” 2015 resulted in improving test cycles and better controlling of vehicle manufacturers, as well as for the ban of high-pollutant engine technologies in urban centers.Diesel bans in cities are discussed. Renewed focus on tailpipe emissions, NOx and particulates. A lower share of new registered diesel cars has been recognized within the EU.
- Call for low emission engines/fuels, and electrification in cities
- Increased interest in methane
  - CNG to move away from diesel
  - LNG for HDV long distance transport
  - LNG for shipping
- Ongoing technological development in HDV for ED95
- Fuel use in China and India is forecasted to increase rapidly in the next decade, and is generally causing higher GHG emissions and local pollutant emissions per kilometre driven than in Europe.
- The growth in the use of biofuels in 2016 displays a slight increase of 1.3% (14.4 Mtoe) (Biofuels Barometer 2017) with biodiesel still dominating by far (80% of biofuels on the market), see Figure 1
  - Currently electric vehicles seem to be more attractive than biofuels to politicians and decision makers (limit on 1st generation biofuels, increased calculation factors for electricity in transport, appraisal of CO2 emissions)
  - The new Directive 2014/94/EU on the deployment of alternative fuels infrastructure very much focuses on electricity and gaseous fuels, with less focus on liquid biofuels
  - The differentiation between the fossil and renewable energy is not well defined

ROAD VEHICLES

Fuels standards:

- Process to increase ethanol content in petrol and FAME concentration in diesel under way
- EN standards for E85 and paraffinic diesel are approved in 2018 respectively
- ISO and ASTM standards for DME as a diesel fuel are approved

Impacts of new emission regulations:

- The new emission regulations (Euro 6 for passenger cars and Euro VI for heavy-duty vehicles) pose some challenges to the use of alternative fuels (e.g. low-temperature performance of FFVs, methane emissions of gas engines)

MARINE

The new IMO sulphur oxide limits in emission control areas (Baltic Sea, North Sea) will require low-sulphur fuels (0.10 % m/m as of 1.1.2015) or alternatively the use of exhaust scrubbers

AVIATION

- Sustainable biofuels are an important building block of the aviation industry’s climate strategy, contrary to the automotive sector aviation will totally depend on liquid hydrocarbon fuels for the next decades
- Several new bio-jet varieties have been approved since 2015
- CORSIA agreement in 2017.

R&D RECOMMENDATIONS

- Energy efficiency efforts for new engine concepts are necessary to reach CO_2 targets, and they could benefit from an improved utilization of well-defined renewable fuels.
  - New engine concepts
  - Fuel cells
- Renewable liquid and gaseous fuels will be needed to reach CO_2 targets.
- Continued efforts on WTW and LCA assessment of fuels needed.
- Further scenario work needed for evaluation of "best fit" of fuels
  - Low emission requirement for urban areas -> electrification (possibly combined with near zero emission conventional engines)
  - Energy density and range can motivate liquid or gaseous fuels in non-urban areas
- Deepen the understanding of fuel, engine and exhaust interactions through modelling and experimental work, e.g., models for combustion and emission formation, fuel oxidation stability, physical properties (e.g. viscosity in extreme conditions), lubricity, material compatibility, performance of multicomponent blends etc.
- Engine performance optimization for high quality biofuels making use of fuel detection
- Make high quality advanced biofuels attractive to vehicle manufacturers by demonstrating emission and/or engine efficiency benefits, increase cooperation with ERTRAC
- Demonstrate the cost effectiveness of biofuels for GHG emission reductions in in various sectors of transport (road, marine, aviation) to keep biofuels on the EU 2030 climate and energy agenda
- Work to ensure that high concentration biofuels are taken into account in the national implementation plans on Directive 2014/94/EU
- Work to ensure a fair appreciation of CO_2 emissions of vehicles running on biofuels (well-to-wheel approach, electric vehicles and vehicles running on renewable fuel should be treated using equal criteria)
- Further work on fuel standardisation and harmonised practises throughout Europe
- Understanding of "best fit" of alternative energies in the various sectors of transport, biofuels, electricity, synergies and disparities in fuels for different sectors

New fuels on the agenda

- Increased interest in methanol as a fuel, mainly in the marine sector and in captive fleets
- DME research and development projects are still going on, significant interest in electrofuels (power-to-gas, power-to-liquids)
- ED95

8 DEPLOYMENT AND RECOMMENDATIONS

The preparation of this revision of the ETIP Bioenergy Strategic Research and Innovation Agenda has confirmed the important role of biofuels for the sustainable transport sector in the EU as one of the most cost effective ways to decarbonize transport. Nevertheless, biofuels in general, and with few and specific exceptions, cannot compete head-to-head with fossil fuels, such that the decarbonization impact needs to be capitalized to a sufficient extent to make biofuels economically viable to produce at the scale foreseen.

The biofuels sector has struggled with an unclear political framework within the recent years, and currently different biofuels pathways are at various stages of maturity. For that reason key barriers must be overcome for the deployment ranging from technology, awareness and capacity, cost finance, infrastructure and public acceptance in addition to policy and regulatory, institutional and administrative barriers. For conventional biofuels, based on crops or vegetable oils, the Fuel Quality and Renewable Energy Directives and the use of mandates has led to an industry that today delivers almost all biofuels on the market. However, it has also initiated a still on-going debate on the sustainability of some of these fuels and on possible negative social impacts. The new overall targets for renewable energy in transport and for advanced fuels for 2030 in the RED II therefore require a significant capacity build-up in the coming decade.

For many advanced and innovative technologies, the most pressing issue is to demonstrate the technology at the appropriate scale, pre-commercial demonstration or full industrial scale.
For a full industrial scale of innovative technologies four main issues remain: to find mechanisms to buy-down the technical risks, to establish clear long-term market conditions for biofuels and bioenergy to make projects economically viable, to broaden the feedstock base and to ensure that the delivered biofuel qualities/bioenergy products meet all requirements of the industrial users and final customers.

A significant number of such plants will be required across Europe so that the most promising technologies can take full account of differing geographical and climatic conditions and logistical constraints. Technologies for the conversion of biomass are evolving rapidly, and their deployment on commercial scale is crucial for triggering a sustainable advanced biofuels industry that would bring substantial environmental and socio-economic gains. Notwithstanding the many (potential) benefits, the implementation of commercial scale projects is slowed down by factors that are not only directly connected with low energy prices, the global crisis or national economic trends[87]. At the same time when technological barriers are removed or significantly mitigated, new obstacles are jeopardizing the deployment of advanced biofuels industries. The main weakness is the combination of an uncertain political framework, with a lack of coherent strategies, the action plans at the European and at the national level, the biomass market (where value chains needs to be very integrated to ensure the supply of the specified feedstock in quantity over time), the context of a growing competition between different end-uses and the resulting local variability of prices. These factors are deterring investors, so that the whole sector is facing a "go-slow". Investment in biofuels projects, including serving debt over 10-12 years from start of production is not possible without guarantees of regulatory stability. A clear and coherent legislation is a key to reduce these non-technological barriers, but also soft measures in the financial sector and coordinated actions. With an enabling policy technologies can start operating in the market on a level of playing field. It would also facilitate innovation, supply and therefore increase the end-use. The integration of renewable biofuels and bioenergy into

[87] Renewable Energy Policies in a Time of Transition. s.l. : IRENA; REN21; IEA, 2018. ISBN 978-92-9260-061-7.

institutional frameworks as well as into the daily life of consumer is an essential part of the energy transition and needs to be further established. The EU represents a union of 28 Member States therefore policy has to take the specific national and local circumstances into consideration as well as to create and design a policy that reflects those circumstances[87].

To meet the international climate targets and the two degree target set in the Paris Agreement, renewable energy and energy efficiency need to scale up much faster than in the past[71]. For that matter one can expect that beyond 2030, the needs for decarbonisation and hence for biofuels, will increase, such that in addition to the deployment of today's mature or close-to-mature technologies and feedstock', new technologies need to be developed by R&D and in pilot plants.

To define a perfect deployment strategy is a complex affair due to the complexity of the market and its way of working. For that matter just highlighting the technology development and integration within existing industry will not be enough. It will need to be coupled to research and development regarding markets, business models, novel value chain cooperation, policy instruments etc. The development of technology and market needs to go hand in hand. This could be addressed both by forms (supporting and collaboration actions) and focus/ content in R&D projects (cross-disciplinary research projects as well as "conventional" research projects). On a long-term view,

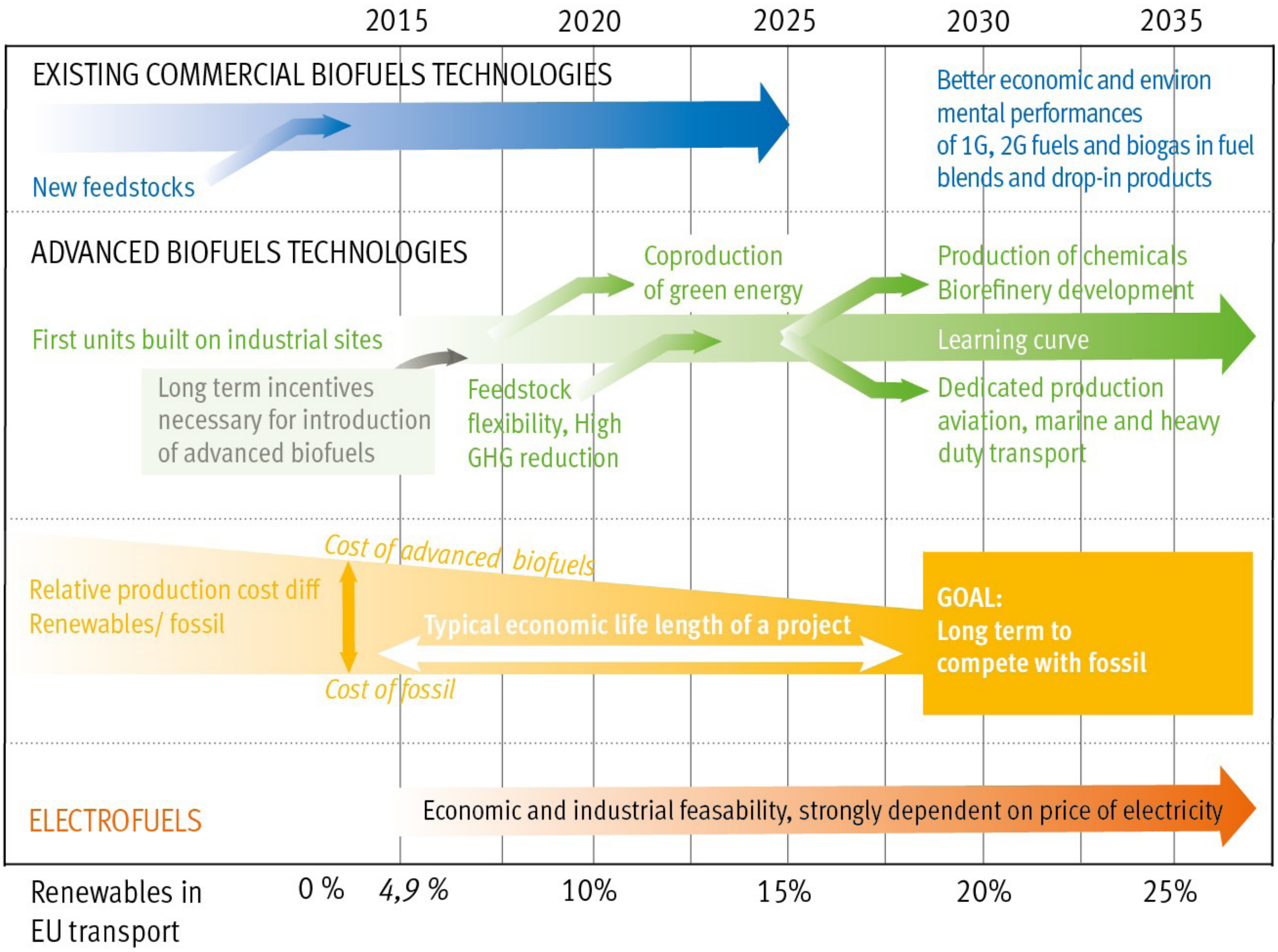


Figure 6: Biofuels deployment (Source: EBTP SRIA 2016, p. 25)

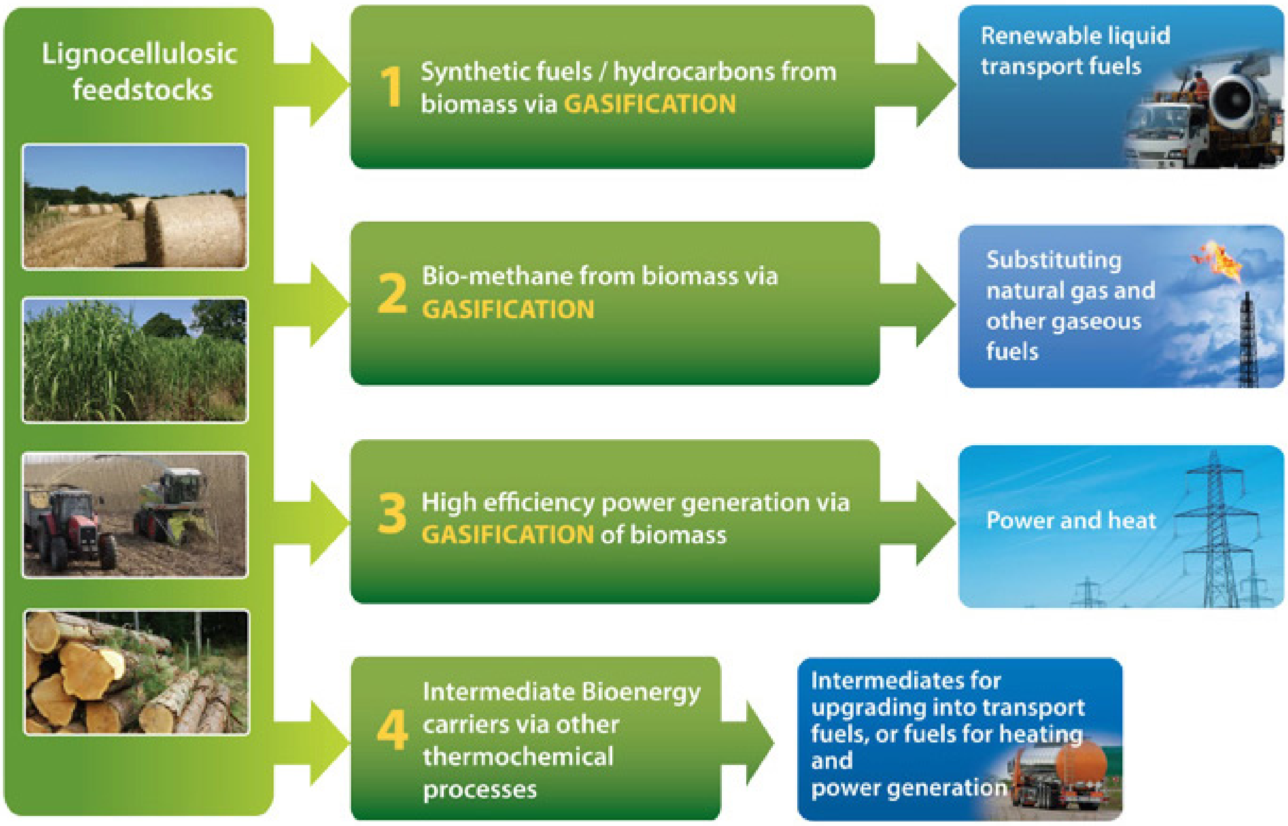
[87] Renewable Energy Policies in a Time of Transition. s.l. : IRENA; REN21; IEA, 2018. ISBN 978-92-9260-061-7.

all topics described in previous chapters like biomass availability, conversion process, end users and the markets and regulations need to be taken into a holistic approach.

Figure 6 illustrates the idea of the future biofuels deployment. At the current stage commercial biofuels technologies (1st generation) are existent and first units of advanced biofuels (2nd generation) technologies are being built. The conversion towards advanced biofuels needs to connect to the current biofuels industry and its ambition to improve the economic and environmental performance from existing plants and technologies. In parallel existing and new players will be involved in the introduction of advanced biofuels to the market.[72]
Advanced biofuels technologies have entered the market and are still in the beginning of the learning curve. These new technologies need to explore the potential of feedstock flexibility, possible co-productions and possibility to combine process schemes with the emerging biochemical industry into so called bioeconomy. This lengthy process will be dependent on long term incentives and political frameworks. The goal is that society develops general scenarios where emission of fossil carbon comes with a cost and thus helps to even out the difference between carbon neutral fuels and their fossil counterpart. Long term introduction of advanced biofuels will also be dependent on other costs, such as investments in new vehicles or alternative logistic systems. In the long term there will be considerable cost reductions associated with the fuel production due to things like advancement in technology, economy-of-scale effect, development of more advanced primary energy production etc. Figure 6 indicates that the gap between production cost of fossil and renewable fuels over time will decrease, but it remains difficult to foresee when and to which extent this will develop. It is likely that externalities of fossil and biofuels have to go into the balance by regulatory measures to provide drivers for introducing biofuel technologies and expanding the industry to achieve decarbonization targets. Long term incentives bridging the gap need to be revisited on a regular basis and the incentives need to be adapted to the commercialisation process of the advanced biofuels but also to reflect the factual reality of the GHG issue.

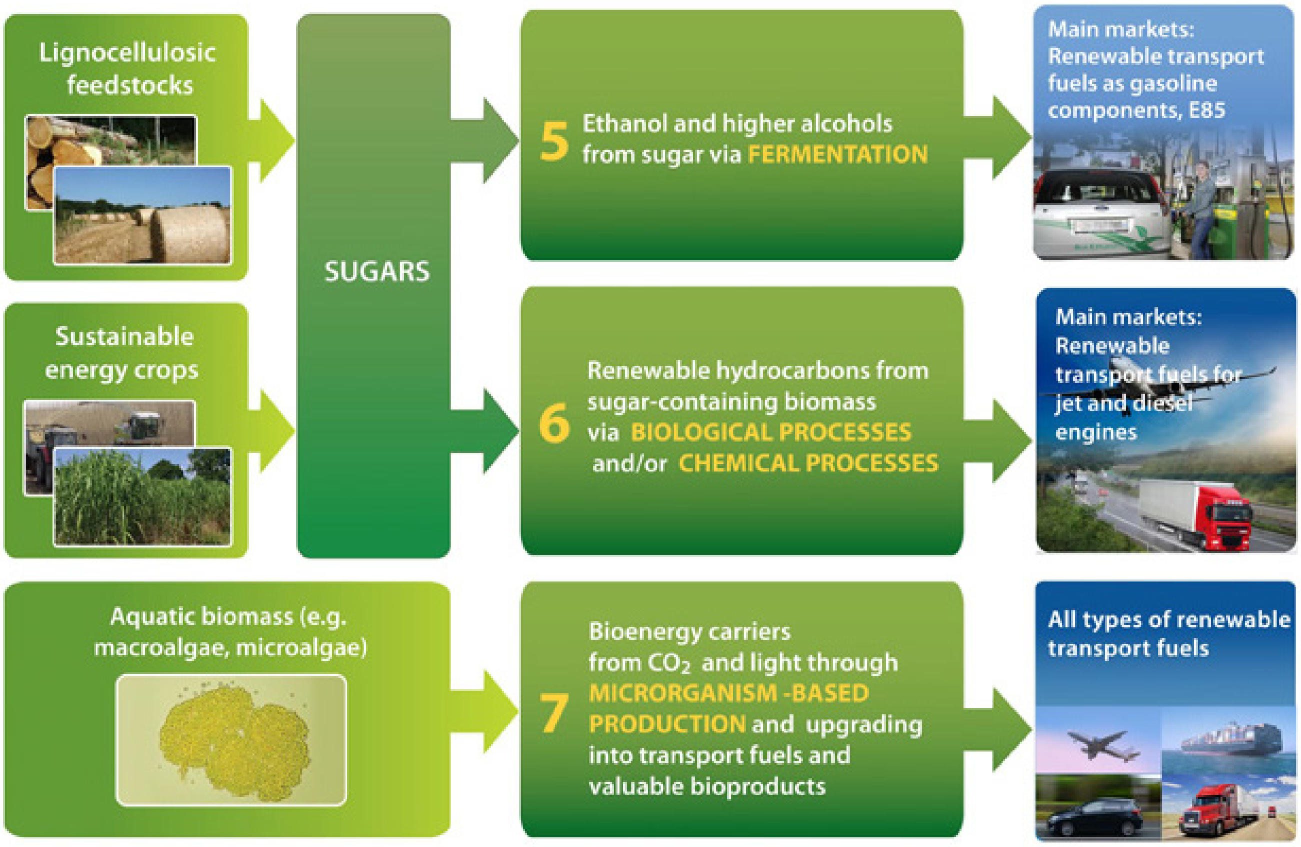
[72] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013PC0017&from=EN

9 Annex 1: EIBI thermochemical value chains[88]



[88] http://www.besustainablemagazine.com/cms2/bioenergy-and-biofuels-innovation-and-technology-progress/
http://www.biofuelstp.eu/eibi.html , http://www.etipbioenergy.eu/value-chains/conversion-technologies/advanced-technologies

10 ANNEX 2: EIBI BIOCHEMICAL VALUE CHAINS[89]



[89] http://www.besustainablemagazine.com/cms2/bioenergy-and-biofuels-innovation-and-technology-progress/ http://www.biofuelstp.eu/eibi.html , http://www.etipbioenergy.eu/value-chains/conversion-technologies/advanced-technologies

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