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Deliverable 5.2

Title:	
MARKET FRAMEWORK DESCRIPTION FOR LIQUID BIOFUELS IN ROAD TRANSPORTATION AND AVIATION	
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1. Introduction

The BECOOL project aims to develop innovative and sustainable value chains for producing advanced biofuels based on lignocellulosic biomass. An important element of this project is the development of biomass-to-advanced fuel value chains while combining and integrating the different key research activities of the project into a consistent framework. Throughout the project, an integrated sustainability and market framework assessment will help to flag opportunities for an optimisation of the biomass-to-advanced fuel value chains based on economic and environmental criteria and to identify the most promising value chains under current and future market conditions.

1. Objective and scope of this deliverable

The objective of this deliverable is to outline and characterise potential markets for the advanced fuels analysed in the BECOOL project. The analysis will put a regional focus on the EU and its existing framework, influencing the use of advanced fuels in different sectors and applications. Potential markets for the BECOOL advanced fuels will be described with regards to:

- Existing incentives or promotion mechanisms,
- Indications regarding the size of the market and its potential future development,
- Potential competitors for the "BECOOL advanced fuels" in the relevant markets.

This report is part of BECOOL WP 5, which, amongst others, will evaluate the competitiveness of different BECOOL value chains. The first step towards this assessment is the analysis of current and future markets for advanced fuels in the EU.

Since the technological concepts under investigation in the BECOOL value chains produce liquid biofuels which can meet different fuel specifications and qualities, the potential applications and markets for these fuels are, from a technical perspective, manifold. In this report, we will focus on two potential markets for advanced fuels in the EU. Consequently, the existing framework for the use of advanced fuels in the two sectors:

i) road transportation and
ii) aviation will be analysed.

The next chapter of this report will briefly introduce and describe the most relevant elements defining the current market framework for the application of advanced fuels in the two sectors mentioned above. Whenever possible, the description will include both, a characterisation of the current framework and, if applicable, an outlook on potential future developments, relevant for the use of advanced fuels.

Chapter three of this deliverable will present a brief discussion and an outlook on potential future markets for the value chains or for parts of the value chains analysed in this report.

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2. Current and medium-term markets

This chapter will characterise the current frame conditions for the use of (advanced) biofuels in the markets of the EU road transportation sector and the aviation sector. Amongst the two sectors, the road transportation sector seems to be more advanced with regards to the existing market framework for the use of (advanced) biofuels. Furthermore, the policy framework between the road transportation sector and the aviation sector do partly overlap (e.g. with regards to the promotion of alternative aviation fuels).

2.1. Use of biofuels in global and EU road transportation

Throughout the recent years, the use of biofuels has increased significantly on a global level (compare figure 1). Within the timeframe from 2006 to 2018, global production has more than tripled. Amongst the biofuels produced, liquid biofuels produced from dedicated crops which substitute fossil diesel and gasoline for road transportation are the dominant biofuel pathways. (Naumann et al. 2019; F.O. Licht 2018b)

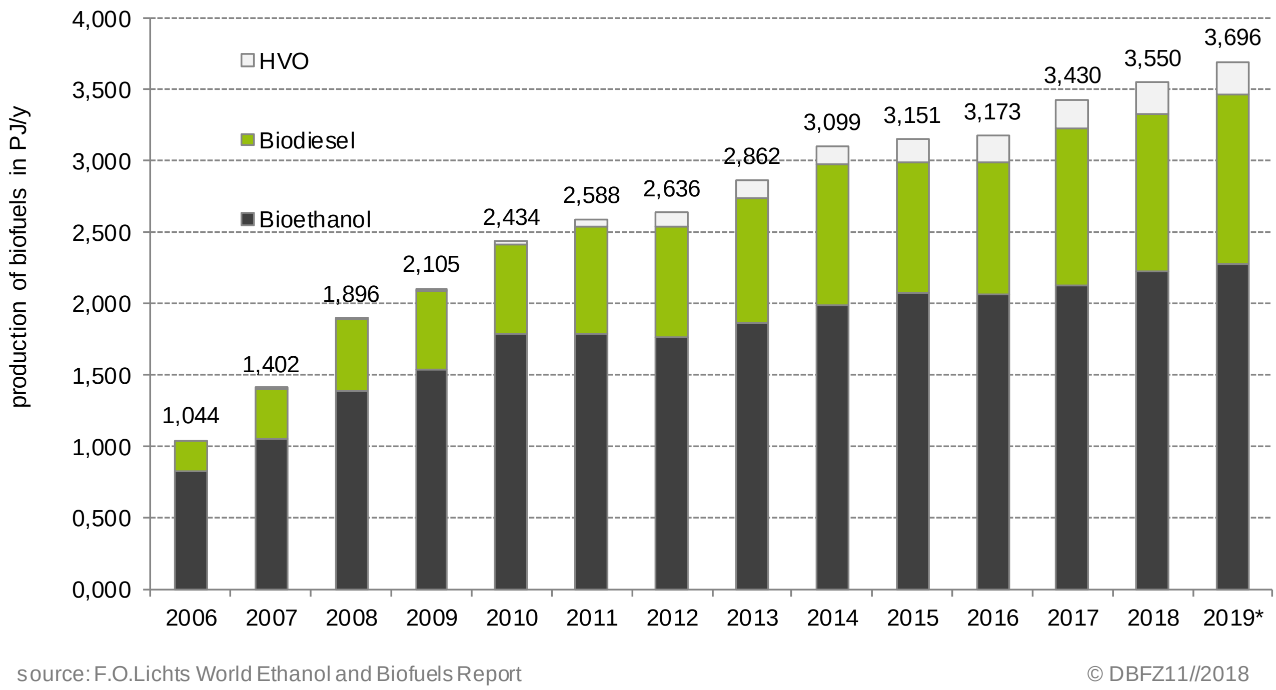

Figure 1 Global production of biofuels 2006 – 2019 in PJ/a (Naumann et al. 2019; F.O. Licht 2018b)

Approximately, two third of the globally produced biofuels is bioethanol as a gasoline substitute, mostly produced from sugar or starch-based crops such as sugarcane, corn, sugar beet as well as different cereal crops. Biodiesel as a Diesel substitute is produced mainly from vegetable oils such as palm oil, rapeseed oil, soybean oil and sun flower oil, as well as from used cooking oil or animal fat.

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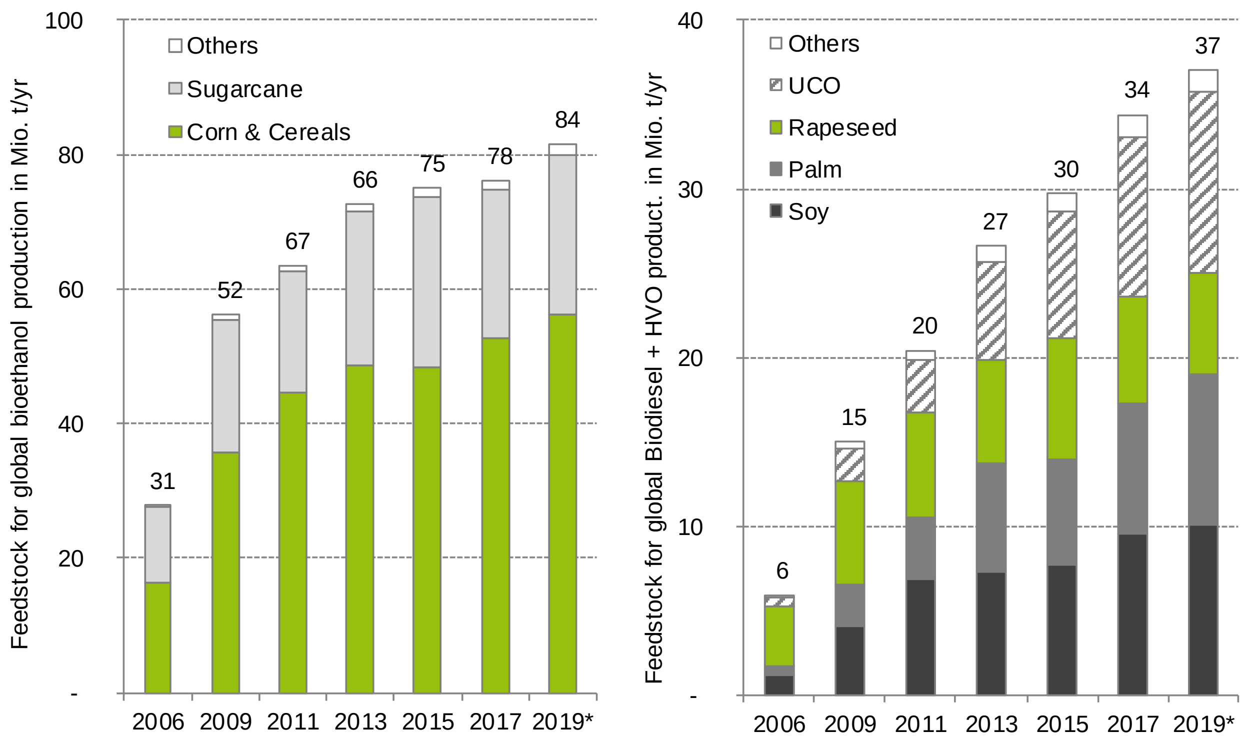

Figure 2 Feedstock base for biofuels used in EU (Naumann et al. 2019; F.O. Licht 2018b)

The regulatory framework for the promotion of biofuels on a global level differs significantly between regions and countries. However, several countries or regions have defined targets for the development of a specific share of biofuels as part of their overall energy consumption in the transportation sector (compare figure 2). Targets can, for example, aim at increasing the overall consumption of renewable fuels (including biofuels) in the transportation sector of a country or the increasing use of renewable fuels in specific sectors of the overall transportation sector (e.g. blending targets for diesel, gasoline, the promotion of dedicated biofuels in specific niche applications as, for example, the agricultural sector).

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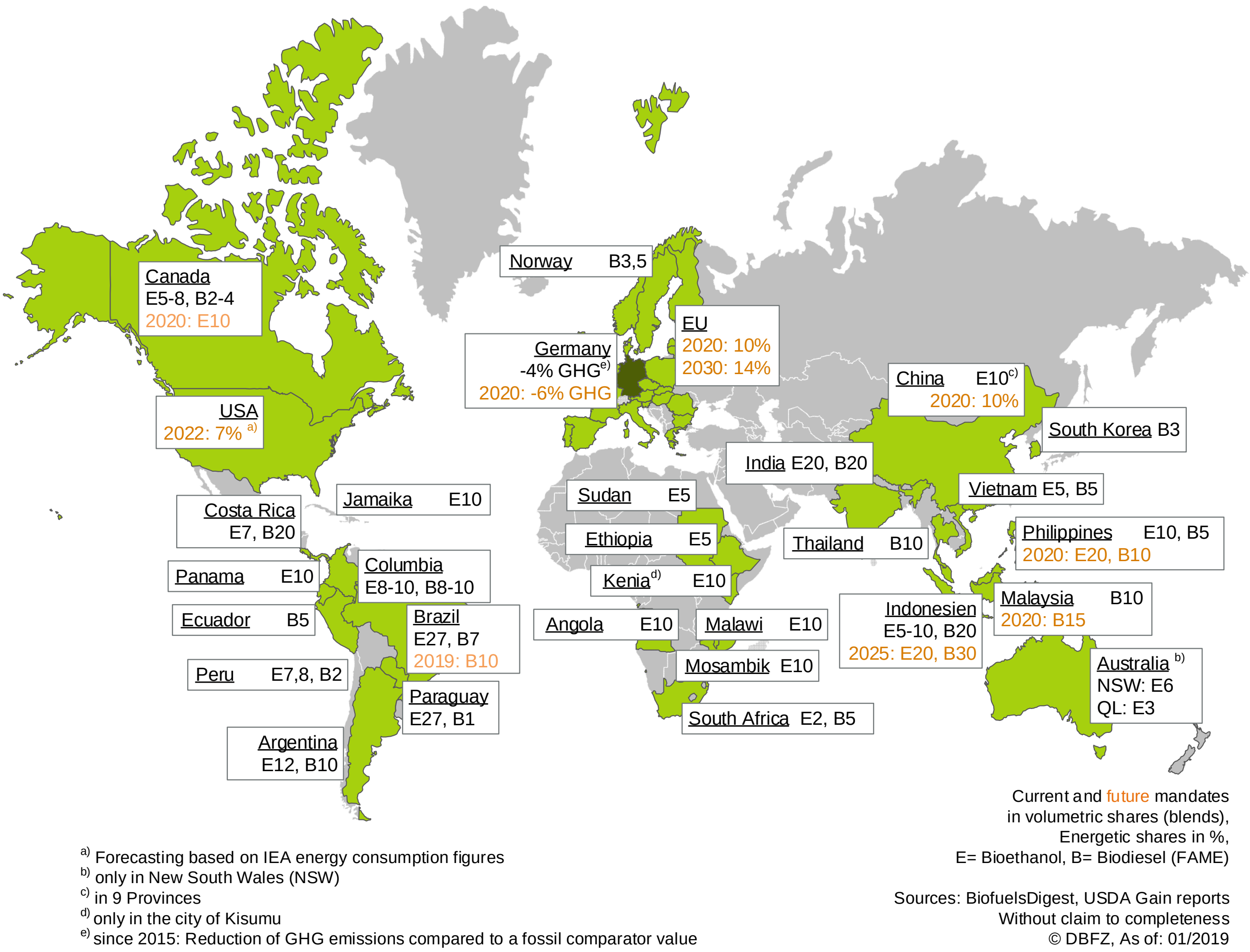

Figure 2 Global targets for biofuel market development (Naumann et al. 2019)

Compared to the global biofuel production and consumption figures, more Biodiesel than Bioethanol is produced and used within the EU. On a European level, biodiesel is currently produced in approximately 200 plants (with a total production capacity of around 20 million tonnes per year). In addition, about 15 plants are currently producing Hydrotreated Vegetable Oil (HVO) fuels (with a total production capacity of 4 million tonnes per year).

In 2018, about 9.2 million tonnes (F.O. Licht 2018b) biodiesel, which corresponds to about 340 PJ, have been produced in the European Union. The biggest biodiesel production capacities are located in Germany and France. The production of HVO in Europe has so far been concentrated mainly in the Netherlands and Finland. In 2018, a total of around 2.8 million tonnes HVO, corresponding to ~120 PJ has been produced. This means, that ~80% of the total installed capacity (3.9 million tonnes) was used (F.O. Licht 2018b). In addition to the production of HVO in dedicated production facilities, HVO is also produced in co-processing (co-refining) units of refineries, together with conventional (fossil) fuels.

The current production capacity for bioethanol as a transportation fuel in the European Union amounts to ~10 million tonnes (about 125 plants in operation). (F.O. Licht 2018a) The total production in the EU in 2015 was around 5.3 million m³ (F.O. Licht 2018b), which corresponds to about 112 PJ. The capacity utilisation of the plant is thus 53% on average. (Calculated according to (F.O. Licht 2018b)).

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The following figure shows the development of both, EU production and consumption for Biodiesel and Bioethanol within the 2006 to 2018 timeframe.

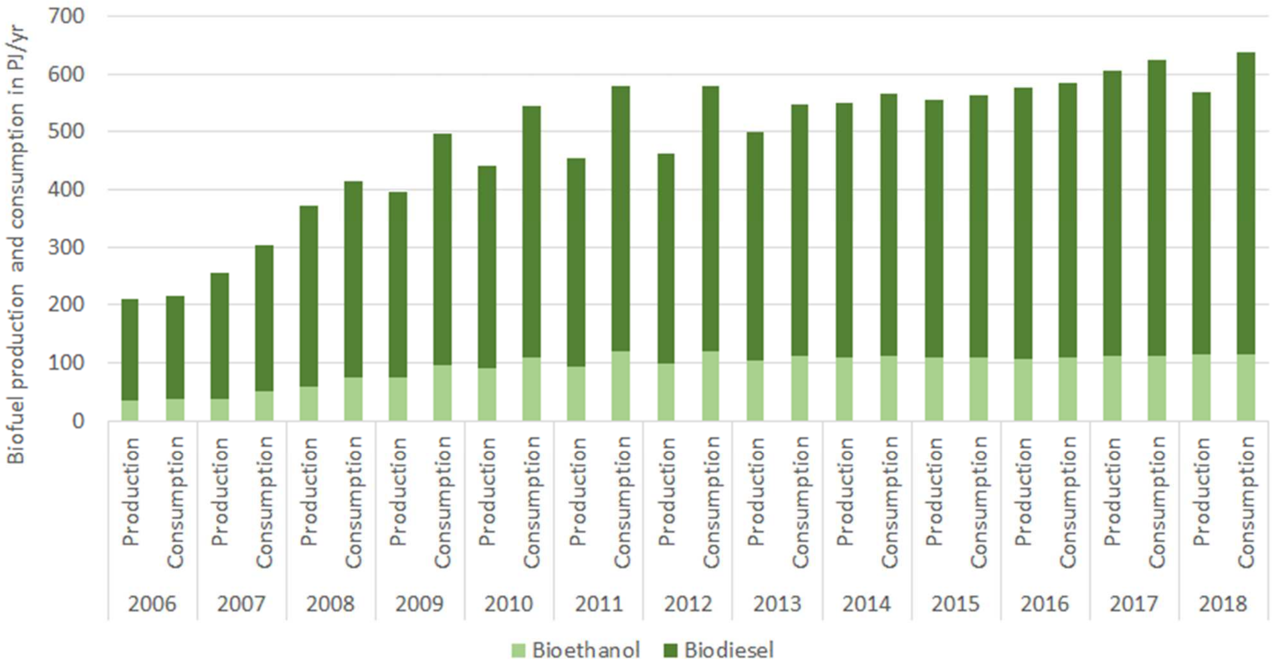

Figure 3 Biodiesel and Bioethanol production in the EU, based on (Naumann et al. 2019)

The current use of biofuels in the EU and its development over the recent years is a direct consequence of the political framework, which sets the boundaries for an EU biofuel market. The next subchapters will focus on the description of the most relevant elements of the policy framework for the use of biofuels in the EU.

2.1.1. Political framework for EU road transportation

Regarding the current framework for the promotion of (alternative) fuels (including biofuels) in the EU, two directives have to be highlighted. The Fuel Quality Directive (FQD) defines a target for the reduction of the total GHG emissions from the use of transportation fuels in the EU (European Commission 2009b). Thus, in case a biofuel emits less Greenhouse Gas (GHG) emissions than a fossil fuel, the use of biofuels has become one option for the obliged parties (e.g. mineral oil companies) to achieve the FQD targets. Secondly, the Renewable Energy Directive (RED), which has been published in 2009, has defined two important elements, framing the market conditions for biofuels (European Commission 2009a). These elements include a target for the share of renewables in the total energy consumption of the EU transportation sector in 2020 as well as a number of sustainability requirements for biofuels.

Fuel Quality Directive (2009/30/EC)

The 2009/30/EC Directive, published in 2009 and changing the former 98/70/EC Directive, which relates to the quality of diesel and petrol fuels, aims at a monitoring and reduction of the lifecycle GHG from transportation fuels. For this purpose, a system was introduced which obligates the fuel suppliers to communicate greenhouse emissions for the fuels they deliver, and to reduce these emissions from 2011 onward. (European Commission 2009b)

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The central goal of the directive is a reduction of lifecycle GHG emissions per energy unit for transportation fuels by up to 10 % (in 2020). This reduction of GHG emissions for fuels used in EU transportation should include the following aspects or sub-targets:

a) 6 % emission reduction through the use of renewable energy carriers (including biofuels),
b) a further 2 % (indicative value) through one or both of the following methods:
    i. the use of environmentally friendly carbon capture and storage technologies;
    ii. electric vehicles
c) a further 2 % (indicative) through the use of EU ETS credits.

The directive was last adapted and replaced in 2015 (EU 2015/1513) (European Commission 2015). The most relevant new elements include:

- Use of biofuels in aviation to reduce lifecycle greenhouse gas emissions,
- An increased threshold of at least 60 % (for biofuels from facilities which start operation after 05/10/ 2015) GHG reduction for biofuels needs to be achieved in order to account a biofuel towards the FQD targets.

Consequently, the introduction of the FQD and its focus on the reduction of GHG emissions from the overall product portfolio of transport fuel suppliers in the EU has set an important accent towards the further development of the EU biofuels sector. The directive includes both, a quantitative target for the use of renewable transport fuels (which are currently mostly biofuels) and it establishes an incentive for the use of biofuels with high GHG emission savings. Depending on the specific national implementation of this directive in the different EU member states, the focus on the GHG emission saving performance of a biofuel can induce competition between biofuel producers and thus, drive innovation regarding the optimisation of the overall GHG emission performance of a biofuels value chain.

One example for this development is the national implementation of both, the FQD and the EU RED directive in Germany. In 2015, Germany has introduced a GHG-related biofuel quota, which is a consequent implementation of the main rationale of GHG mitigation through biofuels use in the transportation sector. Because of this GHG-related biofuel quota system, biofuel producers have started optimising the upstream GHG emissions of their specific value chains in order to increase the market value of their product.

RED 2009/28/EC

A second, important legislation which strongly affects the EU biofuel market framework is the directive on the promotion of the use of energy from renewable sources (EU RED), 2009/28/EC (European Commission 2009a). The EU RED has been published in 2009, replacing 2003/30/EC directive. The main element for the development of renewable energies in the EU transportation sector included in the directive is a joint target of a 10 % share of renewables in the EU transport sector by 2020. The second important element for biofuels is the introduction of a set of sustainability criteria. Biofuels must, in order to be accountable towards the overall 10 % target, meet the defined criteria for sustainability.

The sustainability criteria included in the EU RED cover three main elements, namely:

- the introduction of GHG mitigation thresholds for biofuels compared to a fossil reference value,

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- the definition of “no-go-areas” for the cultivation of dedicated biomass feedstock for biofuel production,
- compliance with existing EU legislation regarding good agricultural practices (e.g. EU cross-compliance regulations).

According to the RED requirements, biofuels need to prove a GHG reduction potential of at least 35 % as compared to fossil fuels. This minimum saving in greenhouse gas emissions as compared to fossil references increases to 50 % from 2018 and 60 % for new facilities. In order to prove the potential to reduce greenhouse gases for a biofuel, the directive contains standard values for typical greenhouse gas emissions in grams of CO_2 equivalent/MJ for various biofuel options. System boundaries include the entire chain, from cultivation to use of the fuels.

Feedstock for biofuel production may neither be derived from areas with high carbon stocks nor with high biodiversity values (such as, for example, marshes or permanent grassland, peatlands, forests, etc.).

The following table summarises the three main areas of sustainability requirements included in the directive.

Table 1 Criteria for biofuel provision as per EU Directive 2009/28/EC (European Commission 2009a) and EU 2015/1513 (European Commission 2015)

Sustainable agriculture	Protection of living areas	Greenhouse gas emissions (GHG) mitigation potential
• General compliance with existing EU legislation regarding good agricultural practice (such as cross-compliance)	• No raw material cultivation in areas which had the following status/characteristics after January 2008: - High carbon stocks, - Wetland areas, - Continuously forested areas, - Primary forest - Nature protection areas - Grassland - Peatland - etc.	• 35 % from entry into force and • 50 % from 2018 and • 60 % for new installations with entry into service after 05/10/2015 in comparison to fossil reference fuel (diesel or petrol) with 83.8 gCO_2-eq. * MJ^{-1}

The RED was last amended in 2015 and replaced by the directive EU 2015/1513 (European Commission 2015). The new, so-called “iLUC directive” includes a couple of changes, affecting the use of biofuels for the achievement of the 10% target for 2020. The main new elements and changes made in 2015 are:

- The introduction of a 7% (max.) cap on biofuels produced from grains and other crops with high starch content, sugar plants, oil plants and from main crops primarily harvested for energy production and produced on agricultural areas.
- The introduction of a 0.5% (min.) sub-target for advanced biofuels, which have been produced from feedstock, included in Annex IX, Part A of the directive.

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- The introduction of a potential double counting instrument (meaning, member states can double count the contribution from advanced biofuels towards their targets under the EU RED regime) for the advanced fuels produced from feedstock included in Annex IX, Part A of the directive.
- The introduction of potential multiple counting instruments for the contribution of renewable fuels in rail traffic (counted up to 2.5 times) for electricity in road transportation (counted up to five times) from renewable energy sources.

Regarding the BECOOL activities and the biofuels analysed in BECOOL, the 2015 directive includes a crucial, and highly important new element. With the definition, of a sub-target and the possibility for double counting, the directive has introduced a first incentive for the promotion of advanced biofuels.

It is important to note, that in contrast to existing definitions for first and second-generation biofuels (Kaltschmitt et al. 2016), the definition of advanced biofuels included in the RED focuses purely on the feedstock as distinguishing feature. Consequently, the EU RED includes, in Annex IX, part A, a table with feedstocks for the production of biofuels which would qualify as advanced biofuels under the EU RED regime. Feedstocks included in Annex IX, part A include:

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 of the second paragraph of Article 2.
q) Other lignocellulosic 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.

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t) Bacteria, if the energy source is renewable in accordance with point (a) of the second paragraph of Article 2.

Based on the definitions made so far in the BECOOL project, the BECOOL value chains would fall under point q, which is defined more clearly in Article 2 of the directive. Under the respective paragraph, the text specifies the feedstock as: “lignocellulosic material” means material composed of lignin, cellulose and hemicellulose such as biomass sourced from forests, woody energy crops and forest-based industries' residues and wastes”. According to this specification, several of the feedstocks analysed in BECOOL WP1 could qualify for the production of an advanced fuel under the EU RED definition.

In order to achieve the RED goal (as well as the FQD goals), the Member States are allowed to establish suitable activities such as investment promotion, tax benefits, ratios or penalties in national laws. A current overview of these individual country legal regulations within the European Union can be seen in Figure 19.

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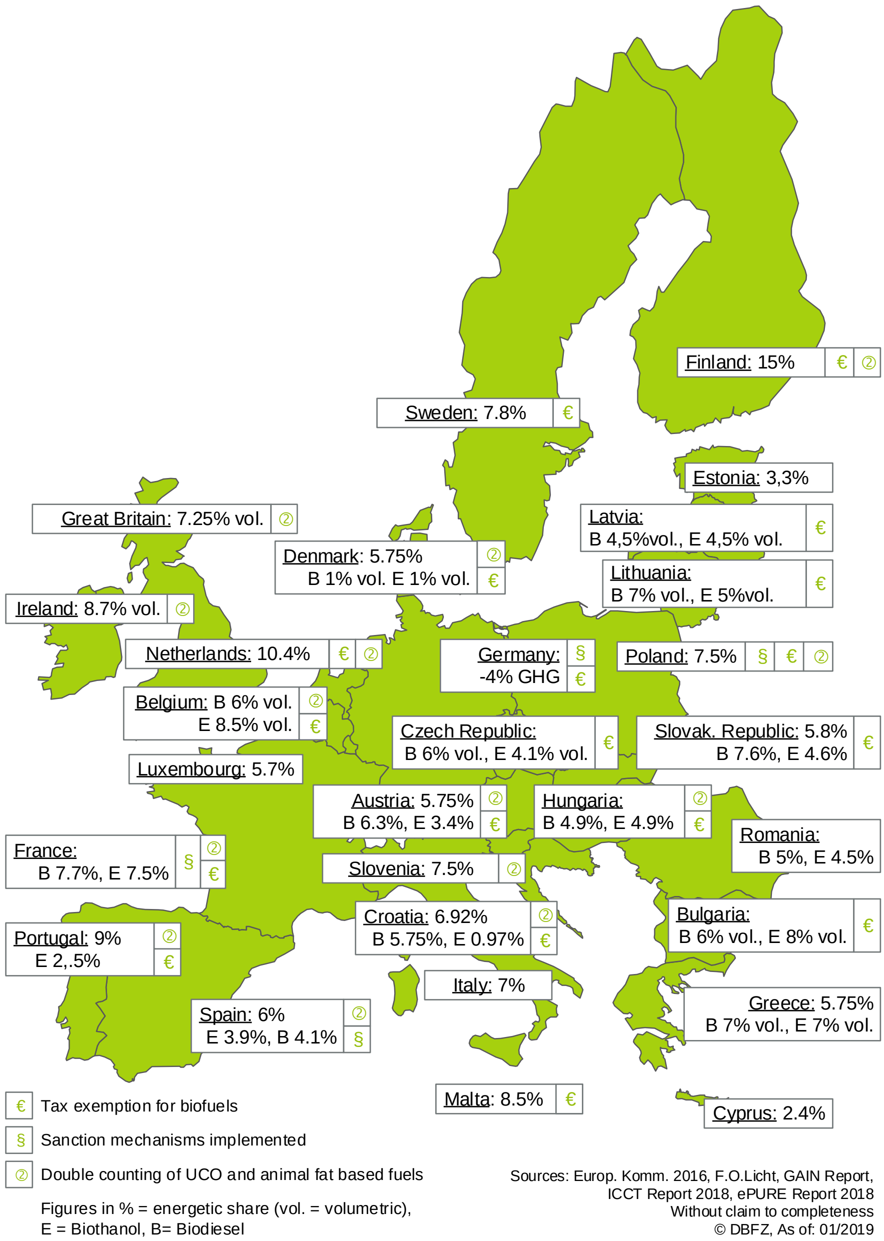

Figure 4 National biofuels quotas and framework conditions in the EU, 2014. Illustration from (Naumann et al. 2016) based on (EC 2016, FLACH et al. 2016, F.O.LICHT 2016a), © DBFZ).

RED II

While the RED has triggered important incentives and market signals for the development of a biofuel market in the EU up until the 2020 timeframe, the recast of the EU RED (RED II) aims at an extension of the this development for the 2021 – 2030 timeframe (European Commission 2018). The RED II has been adopted in late 2018. It includes an advancement and further development of number of elements included in the previous versions of the RED.

An important and overarching element of the RED II is the new overall target for the development of renewables share in EU transportation up until the year 2030. In RED II, the overall EU target for Renewable Energy Sources consumption by 2030 has been raised to 32%. More important for the purpose of the

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BECOOL project is the sub-target for the transportation sector. Member States must require fuel suppliers to supply a minimum of 14% of the energy consumed in road and rail transport by 2030 as renewable energy.

Additionally, the RED II includes a set of detailed requirements, which frame the possibilities and preconditions for the EU member states to reach the overall target described above. An important element in the RED II is the continuation of the sustainability requirements for biofuels, which will be expanded to the production of electricity and heat from biomass. Just as with the previous RED, compliance with these criteria is a precondition for biofuels to be counted towards the overall 14% target. An important element amongst the defined sustainability criteria are the GHG mitigation thresholds for biofuels. Default GHG emission values and calculation rules are provided in Annex V (for liquid biofuels) and Annex VI (for solid and gaseous biomass for power and heat production) of the RED II. Biofuel producers have the option to either use default GHG intensity values provided in RED II or to calculate actual values for their pathway.

The RED II GHG mitigation thresholds for biofuels and bioenergy, which replace the mitigation values from the RED from 2021 onwards, are included in the following table.

Table 2 Greenhouse gas savings thresholds in RED II (European Commission 2018)

Plant operation start date	Transport biofuels	Transport renewable fuels of non-biological origin	Electricity, heating and cooling
Before October 2015	50%	-	-
After October 2015	60%	-	-
After January 2021	65%	70%	70%
After January 2026	65%	70%	80%

In addition to these GHG mitigation values, the existing RED criteria regarding the land requirements for biomass production have also been included in the RED II criteria. Consequently, biofuels, bioliquids and biomass fuels from agricultural biomass must not be produced from raw materials originating from:

- High biodiversity land (as of January 2008), including: primary forests; areas designated for nature protection or for the protection of rare and endangered ecosystems or species; and highly biodiverse grasslands;
- High carbon stock land that changed use after 2008 from wetlands, continuously forested land or other forested areas with trees higher than five meters and canopy cover between 10% and 30%;
- Land that was peatland in January 2008.

The RED II introduces new sustainability criteria for forestry feedstocks and mandates that harvesting takes place with legal permits, that the harvesting level does not exceed the growth rate of the forest, and that forest regeneration takes place. In addition, biofuels and bioenergy from forest materials must comply with requirements which mirror the principles contained in the EU Land Use, Land Use Change and Forestry (LULUCF) Regulation.

To continue the development of advanced fuel markets in the EU, the RED II includes dedicated sub-targets for the use of advanced fuels under the overall 14% target. Consequently, under the RED II framework, advanced fuels must supply a minimum of 0.2% of transport energy in 2022, 1% in 2025 and increasing to at

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least 3.5% by 2030. Furthermore, advanced biofuels will be double-counted towards both the 3.5% target and towards the 14% target.

Additionally, biofuels produced from feedstocks listed in Part B of Annex IX will be capped at 1.7% in 2030 and will also be double-counted towards the 14% target.

Besides the contributions from biofuels produced from Annex IX feedstock, so called conventional biofuels, produced from food and feed crops can be used to achieve the overall target for the transportation sector. However, with the introduction of both, a cap for biofuels from food and feed crops and the sub-target for advanced biofuels, the 2015 version of the RED has started a development, which aims for a change of the feedstock base for biofuels towards an increasing use of biofuels from residues and waste materials. Consequently, the maximum contribution of biofuels produced from food and feed crops will be frozen at 2020 consumption levels plus an additional 1% with a maximum cap of 7% of road and rail transport fuel in each Member State. “Intermediate crops” such as catch and-cover crops are exempt from this cap.

Additionally, fuels produced from feedstocks with “high indirect land-use change-risk” will be limited by a more restrictive cap at the 2019 consumption level, and will then be phased out to 0% by 2030 unless specific batches are certified as “low indirect land-use change-risk.” “Low indirect land-use change-risk” feedstocks include those that are produced on land that was not previously cultivated.

Besides the use of biofuels, other renewables can be used to achieve the 14% target for the EU transport sector in 2030. The RED II sets a strong incentive for the use of renewable electricity, which will count 4 times its energy content towards the target when used in road vehicles, and 1.5 times when used in rail transport. Fuels used in the aviation and maritime sectors can opt in to contribute to the 14% transport target but are not subject to an obligation. The contribution of non-food renewable fuels supplied to these sectors will count 1.2 times their energy content.

European Union: Directives for the development of infrastructure for alternative fuels

Besides the two major policy instruments EU RED and FQD, a third directive addresses directly the development of the infrastructure for alternative fuels in the EU. The 2014/94/EU Directive is also called AFID (Alternative Fuel Infrastructure Directive) (European Commission 2014a). The goal defined with this directive is that EU Member States develop national strategic frameworks for the market development for alternative fuels in transport and for the development of an associated infrastructure. The relevant alternative fuels addressed by the directive are:

- Electricity for transportation vehicles (including an appropriate development of publically-accessible charging stations for electrical vehicles in urban areas by the end of 2020 as well as in the TEN-V core network by the end of 2025, land electrical supplies for inland and oceangoing ships in the TEN-V core network by the end of 2025),
- Hydrogen supply infrastructure for road traffic,
- Natural gas supply infrastructure for the transport sector:
    - LNG (development of LNG service stations in ocean harbours by the end of 2025, in domestic harbours by the end of 2030 as well as in the TEN-V core network for heavy commercial vehicles by the end of 2025, suitable LNG distribution network)
    - CNG (development of publicly accessible CNG service stations in urban areas by the end of 2020 as well as in the TEN-V core network by the end of 2025)

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Goal-setting and perspective for the current and future framework of alternative fuels in the EU

The development of the general political framework for alternative fuels has to be discussed in close connection to the general targets and goals from EU energy and climate policies.

Besides the goals for the development of the use of renewable energies and GHG reduction targets as defined in the EU RED and FQD, the European Union has committed itself to reduce overall GHG emission levels by 80–95 % as compared to 1990 by 2050 (European Commission 2011). This also includes the transport sector, which means, that beside general measures for the reduction of energy consumption, the share of renewable energies in EU transportation must be substantially increased. The following table shows the step-wise energy policy and GHG reduction goals up to 2050 for the European Union.

Table 3 Energy policy goals for the EU: an overview (European Commission 2009a, 2011), (European Commission 2009b)

Sector	Criterion	EU goals			
		2020	2030	2040	2050
Energy in all sectors	Energy consumption	-20 %	-32.5 %		
	GHG emissions (as compared to 1990)	-25 %	-40 %	-60 %	-80/ -95 %
	Share of RE in energy consumption	20 %	32 %		
Energy in the transport sector	GHG emissions	-6 %/ -10 %			
	Share of RE in energy consumption	10 %	14 %		

Besides these targets from existing and implemented policy instruments, the EU 2016 strategy aims at the establishment of a constant process starting a conversion to low-emissions alternative fuels in the transport sector. Key goals for these activities are the reduction of import dependence on petroleum-based fuels and the potential European leadership role in the development of new products, such as advanced biofuels (European Commission 2016). Following the revision of the RED, the EC is currently examining opportunities to implement strong incentives, such as in regards to an obligatory share of renewable alternative energies, including advanced biofuels and synthetic fuels (European Commission 2016).

Besides the use of advanced fuels for road transportation, in the medium term, advanced fuels are considered particularly important for aviation as well as for lorries and buses. In addition, the use of natural gas might increase significantly as an alternative for maritime fuels and as a substitute for diesel used in lorries and buses. The EU's ambitious long-term goal to reduce overall greenhouse gas emissions by 80 to 95 % has not yet been translated into binding milestones after the 2020 timeframe. The following figure shows the current goals for the share of renewable energies in transport for 2020 and 2050.

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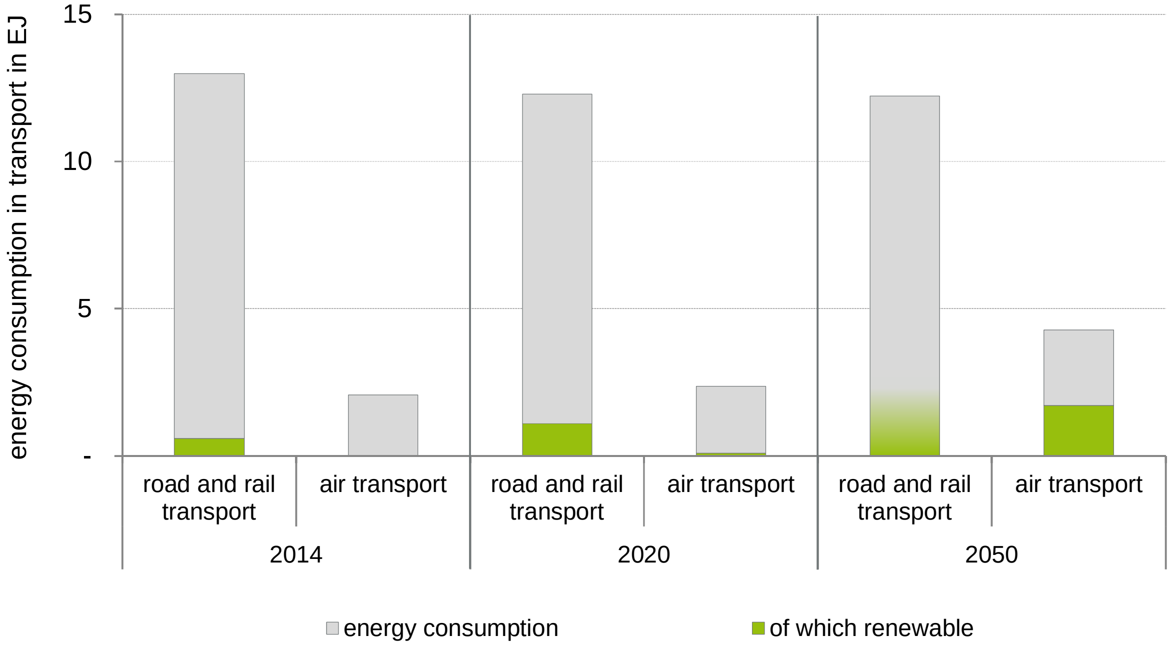

Figure 5 Energy demand in EU road and rail traffic as well as flight traffic, 2013, as compared to the goals for 2020 and 2050. Illustration from (Naumann et al. 2016) based on (European Commission 2011, 2014b; Eurostat 2016).

2.1.2. Market implications for "BECOOL advanced biofuels" in EU road transportation

Based on the description of the main elements in the regulatory framework for the use of advanced biofuels in EU road transportation, this chapter aims at to characterise the potential market for advanced fuels in the timeframe up to 2030.

As described above, the EU RED defines a target of 0.5% (which is, however an indicative target for EU MS) until 2020, the RED II continues this development with (mandatory) targets for the share of advanced fuels in the total energy consumption in the transportation sector of EU member states. Consequently, advanced fuels must supply a minimum of 0.2% of transport energy in 2022, 1% in 2025 and increasing to at least 3.5% by 2030. Furthermore, advanced biofuels will be double-counted towards both the 3.5% target and towards the 14% target. To analyse the market relevance and the importance of this signal towards the development of new technologies and capacities for the production of advanced fuels, in a first step, we will estimate the total amount of advanced fuels needed to fulfil the targets described above.

The energy demand in the EU transportation sector has increased to around 15 EJ per year (Eurostat 2016) by 2006 and has declined slightly since then. The European Union expects an energy demand in 2050, which is comparable to the 2016 level. To which extend this total energy demand for 2050 (taken from the 2013 reference scenario in (European Commission 2014b)) can be further reduced depends on the political measures taken for the achievement of the EU climate policy goals (80% up to 95% GHG-reduction in all sectors compared to 1990).

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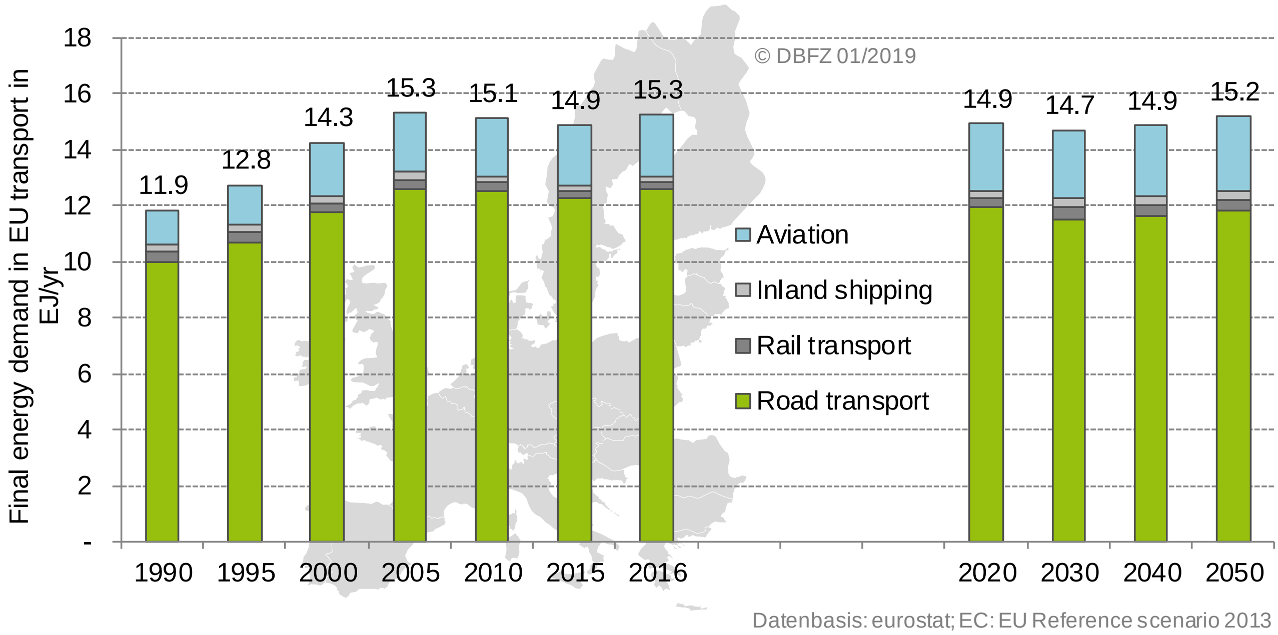

Figure 6 **Energy demand in the EU transport sector, historical growth since 1995 and forecast to 2050. (Naumann et al. 2019) based on (Eurostat 2016; European Commission 2014b)**

Based on this scenario for the development of the energy consumption in EU transport, the RED II targets for advanced fuels (0.2 in 2021; 1% in 2025 and 3.5% in 2030) would translate into a theoretical demand of 25.1 PJ in 2021, 124.1 PJ in 2025 and 428.8 PJ in 2030. It is important to note, that according to article 27 of the RED II, only the energy demand for road and rail transport is relevant for the calculation of the renewable energy needed to fulfil the 14% target.

Given that the RED II allows member states to double-count the contribution of advanced fuels towards the 14% target as well as towards the 3.5% target (RED II), the total demand for advanced fuels might be smaller in practice. However, since the practical implementation of the RED II and thus, the implementation of double-counting rules in EU member states is still pending, we estimate to total demand for advanced fuels based on the RED II target in a bandwidth of 62 – 124 PJ for 2025 and 214 – 428 PJ in 2030.

Since the definition of the term advanced fuels under the RED / RED II framework is based on the feedstock used for biofuel production, in theory, a large number of technologies could be used to process the corresponding feedstocks under Annex IV, part A of the EU RED II into an advanced fuel for transportation purposes. Thus, due to the differences in the conversion efficiencies of advanced fuel technologies and the lower heating values of the resulting fuels, the translation of the energy demand for advanced fuels as described above into a mass-related demand figure is highly uncertain. Assuming a lower heating value for BtL of ~12 kWh per kg, the above mentioned demand of 214 – 428 PJ in 2030 would translate into a BtL demand of approximately 5,000 kilo-tonnes to 10,000 kilo-tonnes. Assuming a production capacity of 200.000 tonnes per year, this equals the production of BtL in 25 to 50 plants.

Assuming that the RED II sub-target will create a "protected market" for advanced fuels, a number of technological pathways suitable to convert the feedstock in Annex IX, part A of the RED II will compete within this market described above. Thus, a first step towards the evaluation of the competitiveness of the BECOOL advanced fuels, which is one of the goals in BECOOL WP5, is the assessment of potential competitors within the advanced fuel sub-target market.

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Considering the characteristics of the qualified feedstock, technology options such as biomethane or the production of synthetic fuels seem to be appropriate. Consequently, we have decided to include three pathways for the production of advanced fuels into our analysis. Please note, that this analysis is a first start, which will be extended throughout the course of BECOOL WP5. For a first estimation, we included the following pathways:

- Biomethane for the conversion of organic wastes and residues
- Bioethanol produced from cereal straws
- Biomass-to-liquid Diesel fuel from lignocellulosic biomass

The concepts to be analysed for this assessment are very different in terms of their plant designs. The difference in those designs is based on scale dependencies by different raw materials and conversion technologies. This results in large differences in the size of the plant. The following short paragraphs include a description of the most important assumptions made for the assessment of the three advanced fuels. Please note again, that the next activities in the BECOOL project aim to polish and to extend this analysis.

Bioethanol from wheat straw

The production of bioethanol from wheat straw is a widely discussed technology option. For this assessment, we are assuming a plant concept with an annual production of approx. 50,000 t of bioethanol with a feedstock requirement of 246,000 t of wheat straw per year. Firstly, the straw is crushed and subsequently broken down into its basic constituents cellulose, hemicellulose and lignin. This is done by using steam and pressure. In the following liquefaction step, hemicellulose dissolves into C5 sugars and cellulose dissolves into C6 sugars with the aid of enzymes. The sugars are subsequently fermented to bioethanol, which is concentrated by means of multiple distillation / rectification and subsequent dehydration, afterwards. The auxiliary energy is supplied via electricity, the process heat via an internal biogas process and a contribution from natural gas. Lignin is dried, pelletized and sold as a high-quality solid fuel. The resulting vinasse is sold as fertilizer.

Biomethane from organic waste

Biomethane from organic waste materials is considered a promising option to achieve the targets defined for advanced fuels. This is the case especially for countries with a highly developed production and distribution infrastructure (e.g. a natural gas grid) such as for example Germany. The biomethane concept analysed for this study is based on a continuous dry fermentation, which is particularly suitable for large processing capacities (> 20,000 t per year). Through the fermentation of approx. 25,000 t of residual substances, a yield of 2,260,309 m^3 per year biomethane can be provided. Apart from a coarse separation of impurities, no pre-treatment of the biomass is required. The process heat required for the fermentation process is provided by a combustion of biogas in a condensing boiler, whereby the auxiliary energy of the entire plant is supplied from the grid. For the treatment of biogas into biomethane, a pressurised water scrubber is planned, having a maximum methane loss of approx. 2 %. The fermentation residue produced can be used as a high-quality organic fertilizer, but must be composted beforehand.

Biomass to Liquid (BtL) from wood chips

For the example Biomass to Liquid pathway in this study, we are assuming an annual production of approx. 188,000 t of Fischer-Tropsch-fuel (FT-Diesel) with an annual feedstock requirement of 1,534,424 t of wood

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chips from short-rotation coppice. The basis for fuel production is a multi-stage gasification of dried wood chips followed by gas scrubbing and conditioning to syngas. Subsequently, it is fed to FT-synthesis in a fixed-bed reactor and converted to FT crude products using catalysts. After product separation, the wax fractions are converted to FT-Diesel by means of hydrocracking using an H_2-feed. Process heat is supplied via natural gas. Saturated steam not used in the process is superheated and used in a steam turbine to generate surplus electricity. The by-products naphtha and electricity are both sold.

For an analysis of the competitiveness of these three advanced fuel pathways in comparison to the BECOOL advanced fuels, the GHG mitigation costs of the fuels are considered to be a meaningful parameter. Consequently, we are estimating costs and GHG mitigation potential of the three fuels analysed.

Feedstock costs are an important first element to estimate the production costs of the three advanced fuel pathways. It is important to note, that the feedstocks defined in Annex IX, part A are no commodities. Contrarily, feedstock prices (or costs for collection) can differ significantly across regions in Europe. For our analysis, we assumed an average price for straw (including transport) of 100 EUR per t (Agrar heute). The price of wood chips is less fluctuating at around 87 EUR per t (at 30 % moisture, including transport) (EUWID). Organic municipal waste as a raw material is completely different in these scenarios as it does not incur any costs or even generates additional revenue through its disposal. These revenues can vary between 35 and 90 EUR per t (figures for Germany). Costs or revenues for the use of organic wastes are unknown for the European region. Due to lower disposal requirements, a conservative estimate for its price of 0 EUR/t is assumed. Depending on the production pathways, the annual operation hours of the production plant are set to 8,000. An annual gross salary of 50,000 EUR per employee is assumed. Maintenance (3 %), insurance (1 %), administration (0.5 %) and unexpected costs (0.5 %) are calculated proportional to the investment costs.

Feedstock costs have a major impact on the production costs for the three advanced fuel concepts. Given the high sensitivity of feedstock costs across Europe, we included a sensitivity analysis. The market for straw is very regional and not yet well developed in most EU member states. Due to the low energy density of straw, it cannot be assumed that straw will be transported over long distances. It is assumed that the use of straw as a raw material for ethanol production creates a competition in the usage, which leads to a shortage of the raw material. As a result, straw costs are expected to increase in the long term. Therefore, straw prices are varied from 100-150 EUR/t. The market for wood chips is larger, more international and – because of this – more stable. In this case, price increases and possible price reductions are assumed. Based on this assumption, the raw material costs varied in the range of 70-105 EUR/t. For the production of biomethane, it is assumed that both revenues and costs could arise from the disposal of biowaste. The impact of these changes is examined in the range of ±10 EUR per t.

Based on these assumptions, we estimated production costs for the three advanced fuels as indicated in the following figure. According to this first analysis, biomethane is the most cost-effective conversion path with production costs of approximately 25 EUR per GJ fuel. BtL-Diesel and bioethanol are at a quite comparable level with production costs between 33 EUR per GJ and 37 EUR per GJ.

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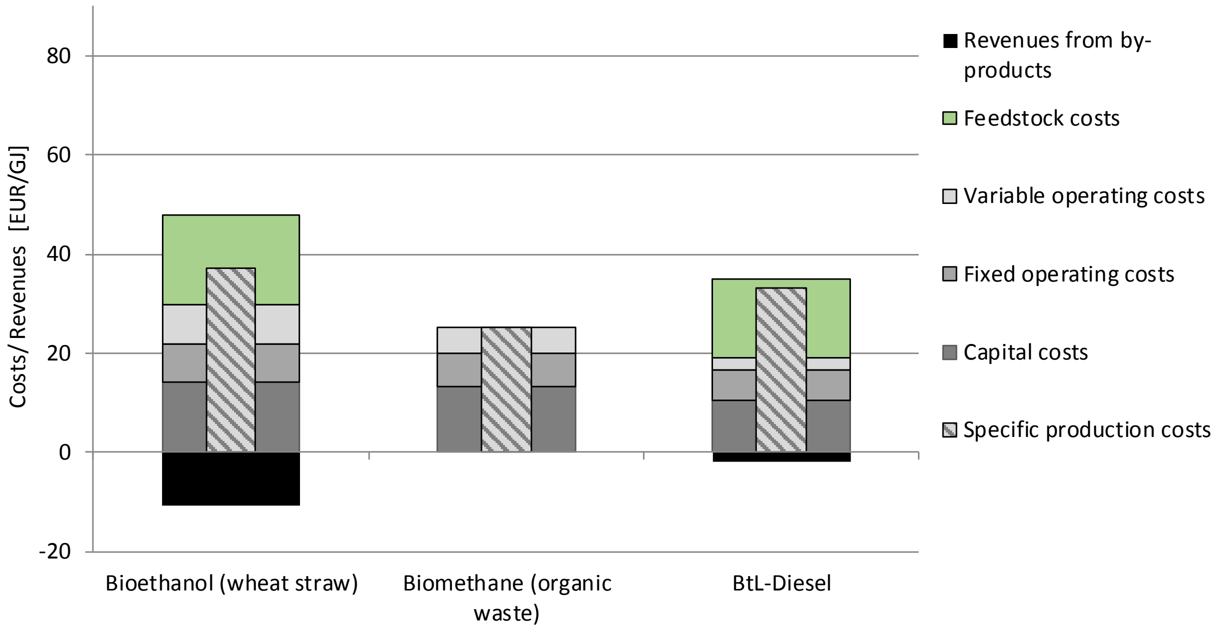

Figure 7 Specific production costs of three exemplary advanced fuel pathways

Considering the huge sensitivities regarding the feedstock prices and supply costs, the following figure shows cost ranges for the three advanced fuels. As a next step in BECOOL WP5, the figure can be expanded to add additional advanced fuels and benchmarking figures for the BECOOL advanced fuels.

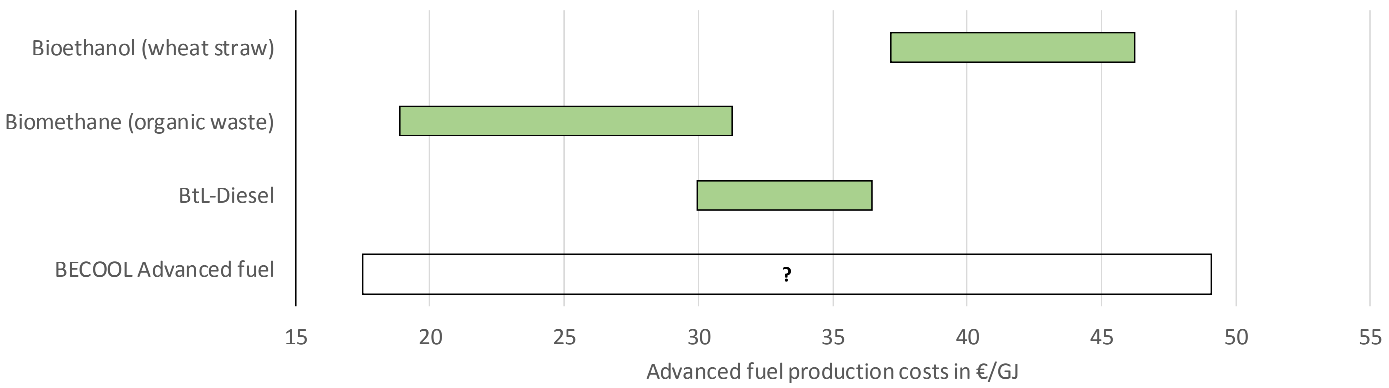

Figure 8 Sensitivity analysis for fuel production costs in € per GJ

As a next step we will estimate the GHG mitigation potential of the three advanced fuel pathways based on literature values (taken from (Zech 2016; Zech et al. 2016; Majer et al. 2018; Majer et al. 2016) . Consequently, production costs and GHG mitigation potentials will be conflated to GHG reduction costs.

The next figure shows the range of the life cycle GHG emissions for the three advanced fuel pathways based on different literature sources. Values for BtL-fuel range from 16 - 49 g CO_2-Eq./MJ. The magnitude of the total result is strongly dependent on the type of feedstock used for BtL-production and the associated GHG emissions from respective upstream processes.

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For the life-cycle emissions of Bioethanol from straw, we observed results in a range of 11 – 41 g CO_2-Eq./MJ . For this pathway, the total result was specifically sensitive to the type of process energy supply (internal vs. external process energy supply). Emissions from biomethane from organic residues show the smallest range compared to the other pathways considered. The total life-cycle emissions from biomethane produced from organic residues based on results from the BIOSURF project range between 15 - 17 gCO_2-Eq./MJ (Majer et al. 2016). Most influencing factors are methane emissions from processing and upgrading as well as the energy carrier used for the supply of process energy.

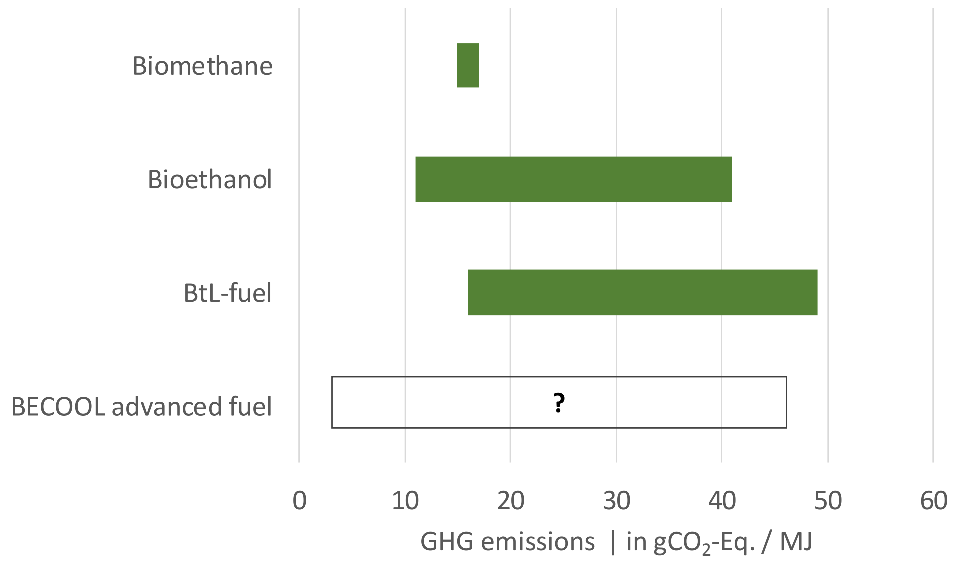

Figure 9 GHG emissions for three exemplary advanced fuel pathways in gCO_2-Eq. /MJ based on (Majer et al. 2016; Majer et al. 2018; Zech 2016; Zech et al. 2016)

In the context of this study, GHG mitigation costs express the price for the mitigation of a specific amount of GHG emissions by using an energy carrier with relatively higher costs and lower emissions compared to a reference fuel. For this first assessment, we have calculated the GHG mitigation costs for the three advanced fuels compared to a fossil reference value. The GHG mitigation for the reduction of 1 ton CO_2-Eq. by a substitution of fossil fuel by alternative fuels has been calculated according to the following equation:

$$C_{GHG\ mitigation} = \frac{C_{advanced\ fuel} - C_{fossil\ fuel}}{GHG_{fossil\ fuel} - GHG_{advanced\ fuel}} = \frac{\Delta C}{\Delta GHG}$$

Equation 1 Calculation of GHG mitigation costs ($C_{GHG\ mitigation}$ in EUR per t $CO_{2\text{-eq.}}$)

With:

$C_{advanced}$ fuel –	Specific production costs of the advanced fuel
$C_{fossil\ fuel}$ –	Specific production costs of the fossil fuel comparator
ΔC –	Additional costs of advanced fuels
$GHG_{advanced\ fuel}$ –	GHG emissions of advanced fuel
$GHG_{fossil\ fuel}$ –	GHG emissions of fossil fuel

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ΔGHG – Net GHG emissions avoided by substituting fossil fuel with advanced fuel

According to this methodology, the mitigation costs are obviously sensitive to two factors: the cost difference between the advanced fuels and fossil fuels and the difference in the specific GHG emissions of both fuels. For the purpose of this study, we differentiated the comparator values for fossil fuels including a value for gasoline (93.3 gCO_2-Eq. per MJ) and diesel (95.1 g CO_2-Eq. per MJ) from the Fuel Quality Directive to calculate the difference between the fossil fuel and advanced fuel GHG emissions. For the fossil fuel comparator, we assumed costs of ~ 13.9 EUR/GJ for diesel and 15.9 EUR/GJ for gasoline.

Based on these assumptions and the cost as well as GHG emission figures presented in the previous paragraphs the GHG mitigation costs for the three pathways analysed have been calculated. Considering the minimum and maximum values from the cost and GHG emission calculations, the assessment of GHG mitigation costs results in a bandwidth with minimum and maximum values for each pathway.

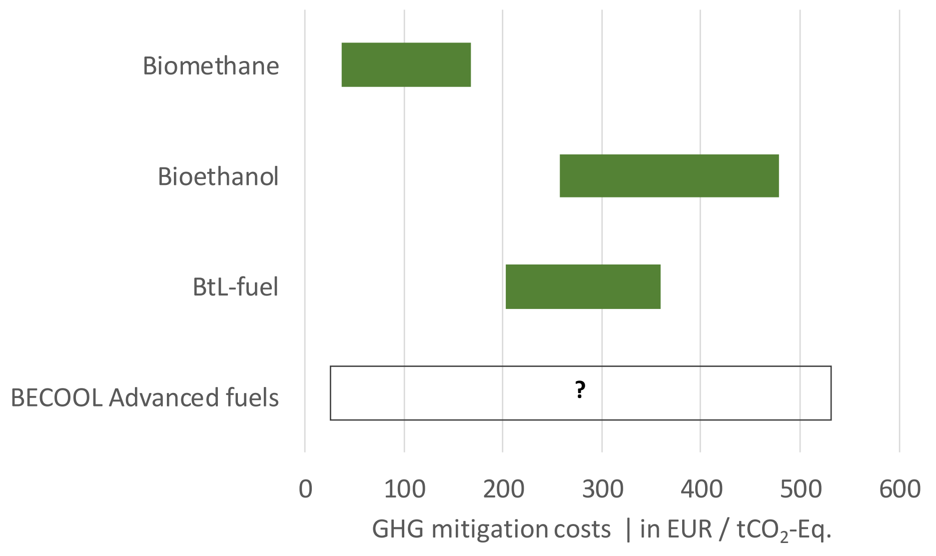

Figure 10 GHG mitigation costs for three exemplary advanced fuels in EUR per tCO_2-Eq.

Based on our assumptions, biomethane from organic waste shows the lowest GHG mitigation costs (calculated in comparison to gasoline, values ranging between 37 and 167 EUR/t CO_2-Eq.). Bioethanol from straw (also compared to gasoline) as well as BtL (compared to diesel) show significantly higher GHG mitigation costs per tonne of CO_2-Eq. The ranges for the result of each pathway are mainly dependent on the type of feedstock used (BtL) as well as the type of scenario for the supply of process energy (both pathways).

The analysis can be extended based on primary data and benchmarking figures from BECOOL processes to allow for a better understanding regarding the competitiveness of the BECOOL advanced fuels compared to different advanced fuels produced from RED II, Annex IX, Part A.

2.2. Aviation

The aviation industry is often considered as a potential future market for renewable liquid energy sources. Consequently, there is a growing interest towards the uptake of bio-based drop-in-fuels by the aviation industry. However, there is currently a low overall use of biofuels, despite an increased number of biofuel

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tests and corresponding research projects. According to (EASA 2016), the share of biofuels in total fuel consumption was 0.05% in 2009(EASAÉ. The current use of bio-based aviation fuels is a direct consequence of the political framework, mainly because there are currently no mandatory legal requirements for the use of bio-based aviation fuels. The following paragraphs will focus on the description of the most relevant elements of the policy framework for the use of bio-based aviation fuels.

2.2.1. Political framework for Aviation

EU RED

The EU Directive 2009/28/EC for Renewable Energy (RED) (European Commission 2009a), which is described in Section 2.1.1, sets a minimum target of 10% renewable energy in the transport sector. Every biofuel that is to be counted towards this target must meet the RED GHG-mitigation and sustainability criteria. The renewable transport target of 10% is defined in the EU only as a share of fuel in the road and rail sector. However, the directive EU 2015/1513 includes the use of biofuels in aviation to reduce lifecycle greenhouse gas emissions, given that the fuels meet the required sustainability criteria

RED II

The EU Directive 2018/2011 (RED II ; description pls. see in section 2.1.1) as recast of EU RED 2009/28/EC sets a minimum share of renewable energy in the transport sector at least 14% by 2030 (European Commission 2009a, 2018). Similar to the EU RED, the RED II target refers to the road and rail sector and again jet fuels can be accounted if they meet the defined sustainability criteria. With the exception of fuels produced from food and feed crops, the share of fuels supplied in the aviation and maritime sectors shall be considered to be 1.2 times their energy content (European Commission 2018).

EU ETS

Aviation has been part of the EU Emission trading scheme (ETS) since 2012. This includes CO_2 emissions from aviation starting from the third phase (2012–2020) of the ETS (European Commission 2008). According to directives 2008/101/EC and 2009/29/EC, CO_2-Emissions from virtually all flights in, out of and within the countries of the European Economic Area (EEA) are basically subject to the same emissions trading obligation. This would cover about one third of global aviation emissions. Biofuels used in the EU ETS are considered as zero GHG emissions. However, to qualify for this zero rating, biofuels must first be demonstrated that they comply with the GHG and sustainability requirements of the RED. This means, for example, that biofuels are taken into account as long as they reach at least the RED minimum GHG saving threshold of 60% GHG compared to fossil fuels. Otherwise, the respective biofuels are treated as a fossil resource.

The application of the EU ETS towards flights that depart from or arrive at an airport outside the EEA ('extra-EEA flights') had been suspended until the end of 2016 (European Commission 2013, 2014c) to allow for the development of comparable measures with global scope by the International Civil Aviation Organization (ICAO), and to avoid conflicts with international trading partners. In October 2016, ICAO adopted a global market-based measure (GMBM), which would become operational in 2021. In February 2017, the European Commission proposed a regulation to prolong the derogation for extra-EEA flights, gradually reduce the number of aviation allowances from 2021 onwards, and prepare for implementation of the GMBM.

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Currently, only flights within the EEA are subject to emissions trading as follows:

- The cap on air traffic ("cap") is 95% of the average ETS-related $C0_2$ emissions from 2004 to 2006, with the possibility of purchasing emission rights from other economic sectors (semi-open system).
- There will be a free allocation of allowances for 85 per cent of this amount on the basis of a valuation procedure and the auction of the remaining 15 per cent.

ICAO

As mentioned before, the EU Decision 377/2013/EU followed an agreement by the ICAO Assembly in October 2013 which aims at developing a global market-based mechanism addressing international aviation emissions (European Commission 2013): the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) which was adopted at the ICAO 39th Assembly in October 2016 (ICAO 2016).

The goal of CO_2 neutral growth of the international Air transport from 2020 (CNG 2020) was launched in 2010 in the ICAO Resolution A37-19, including the target to mitigate CO_2 emissions from air transport (ICAO 2010):

- An average improvement in fuel efficiency of 1.5% per year from 2009 to 2020
- A cap on net aviation CO_2 emissions from 2020 (carbon-neutral growth)
- A reduction in net aviation CO_2 emissions of 50% by 2050, relative to 2005 levels

These targets should be met with the following measures:

- New technology, including the deployment of sustainable alternative fuels
- More efficient aircraft operations
- Infrastructure improvements, including modernized air traffic management systems

However, new technical and operational measures, as well as increased use of biofuels, will not be enough to reduce CO_2 emissions, at least for the period from 2020 to around 2037, in order to achieve this goal. An additional market-based measure ("Economic Measure") is therefore intended to close the remaining gap to the existing set of measures during the period in question. This is done with the system CORSIA. In this context, CORSIA aims to reduce emissions from the aviation sector by the purchase of offset certificates, which can be acquired by other sectors that carry out climate protection projects (climate compensation system). ICAO has decided on a phase-in implementation of CORSIA (ICAO 2016):

- a pilot phase (2021–2023) and
- a first phase (2024–2026) which are voluntary and
- a second phase (2027–2035) applying to all States except the exempted States unless they volunteer to participate.

The basket to achieve the CO_2 mitigation target now contains the following measures:

- Aircraft-related technology development – purchase of new aircraft and new equipment to retrofit existing aircraft with more fuel-efficient technology.
- Alternative fuels – investments in the development and deployment of sustainable aviation fuels.
- Improved air traffic management and infrastructure use – improved use of communication, navigation and surveillance/air transport management (CNS/ATM) to reduce fuel burn.

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- Economic/market-based measures – researching and building awareness of low cost, market-based measures to reducing emissions such as emission trading, levies, and off-setting.

That means, emission reductions may also be claimed through the use of “sustainable aviation fuels” (SAF) implied that they meet the following defined sustainability criteria (ICAO 2017, 2010):

- SAF need to prove a GHG reduction potential of at least 10 % as compared to conventional aviation fuel (CAF) on a life cycle basis
- SAF will have to be produced by fuel producers that are certified by an ICAO-approved sustainable certification scheme. For such a scheme to be approved by ICAO, it will have to meet a set of requirements to be determined by ICAO.
- SAF must not produced from biomass cultivated in areas with high carbon stocks.

But currently within ICAO’s efforts there is no binding alternative fuel consumption mandate, so that the long-term deployment of alternative fuels depends currently on national-level policies and the relative costs of alternative compliance methods such as carbon offsets. But quantified targets are to be agreed at the next ICAO Conference on Aviation and Alternative Fuels due to take place by 2025.

2.2.1. Potential markets for BECOOL advanced biofuels

Henceforth, the expected strong growth of the aviation sector might lead to an increasing demand for alternative aviation. (Thrän und Ponitka 2016). Throughout the recent years, several of the preconditions necessary for the market implementation of alternative biofuels in aviation have been achieved (demonstration, technical standards etc.). Furthermore, the International Civil Aviation Organization (ICAO) is committed to achieve 50 % emission reduction in the international aviation by 2050, relative to 2005 levels (ICAO 2010), the EU Fuel Quality Directive aims at reducing GHG emissions by 6 % until 2020, compared to 2010 for all energy used in the transport sector (European Commission 2009b) and the RED II sets a minimum share of renewable energy in the transport sector at least 14% by 2030 (European Commission 2018). However, despite these existing targets, the lack of binding quotas and several, cost effective alternative options for the reduction of GHG emissions (e.g. GHG offsetting measures) has so far hindered the development of a market for biofuels in the aviation sector. To implement biojet fuels on a broad range there are still major challenges to solve. Mandatory international targets and standards and a stable, long-term policy framework with mandatory blending targets are necessary to achieve economic security.

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3. (Outlook on) potential medium- to long-term perspectives affecting the market framework for advanced fuels

The main objective of this report is the description of the current and medium term market framework for advanced fuels in EU road transportation and aviation. As described in chapter 2, the EU RED and RED II are currently the most important policy instruments for the development of biofuel and advanced fuel markets. The EU RED amendment made in 2015 and the RED II directive currently aim at a shift in the resource base of biofuels used in the EU, from food and feed based crops to waste and residue streams. Consequently, new technologies and production capacities need to be developed in order to produce the amounts of advanced fuels as envisaged in the RED II target for 2030. This process will be associated with significant challenges. Mainly, because of the short timeframe of the RED II targets (nine years from 2021 until 2030) which, in combination with the rather small target for advanced fuels, might be a barrier for the necessary investments. Thus, all potential options for the reduction of the production costs have to be considered in the future to support the market implementation of advanced biofuel, especially if based on new and innovative conversion technologies. This includes for example the consideration of new (or economically optimized) by-product routes for advanced biofuels produced in refinery (bio-) concepts to increase revenue streams and the added value for the whole (bio-)refinery concept. Furthermore, continuous political support will be necessary for a successful, large-scale rollout of advanced biofuels.

Considering the medium- to long-term perspective, biomass and bioenergy pathways have to play a decisive role fighting global warming and stabilizing or even reducing global CO_2 levels. In this regard, bioenergy systems combined with carbon capture and sequestration (CCS) or carbon capture and utilization (CCU) technologies offer the potential of carbon neutral or even carbon negative technology pathways. Bioenergy and CCS (BECCS) play a key role in several scenarios and strategies for the development of pathways towards the achievement of the EU long-term goals to reduce overall GHG emission levels by 80% or 95% in 2050. (Rogelj, J., D. 2018) Thus, respective technologies, as in the case of the BECOOL project, advanced biofuels with potential CCS and CCU links need to be developed. The potential systemic contribution of BECCS technologies in advanced biofuel pathways have to be considered in the overall assessment of their economic viability.

Several studies have started to analyze and compare the costs of different CCS options based on various technologies. The literature shows a wide range of cost figures per ton of CO_2 for BECCS options depending on the specific bioenergy pathway and the feedstock used. However, (Budinis et al. 2018; Fuss et al. 2018; Haszeldine et al. 2018) indicate, that BECCS options can be competitive from an economic point of view compared to other CCS options (compare the following figure).

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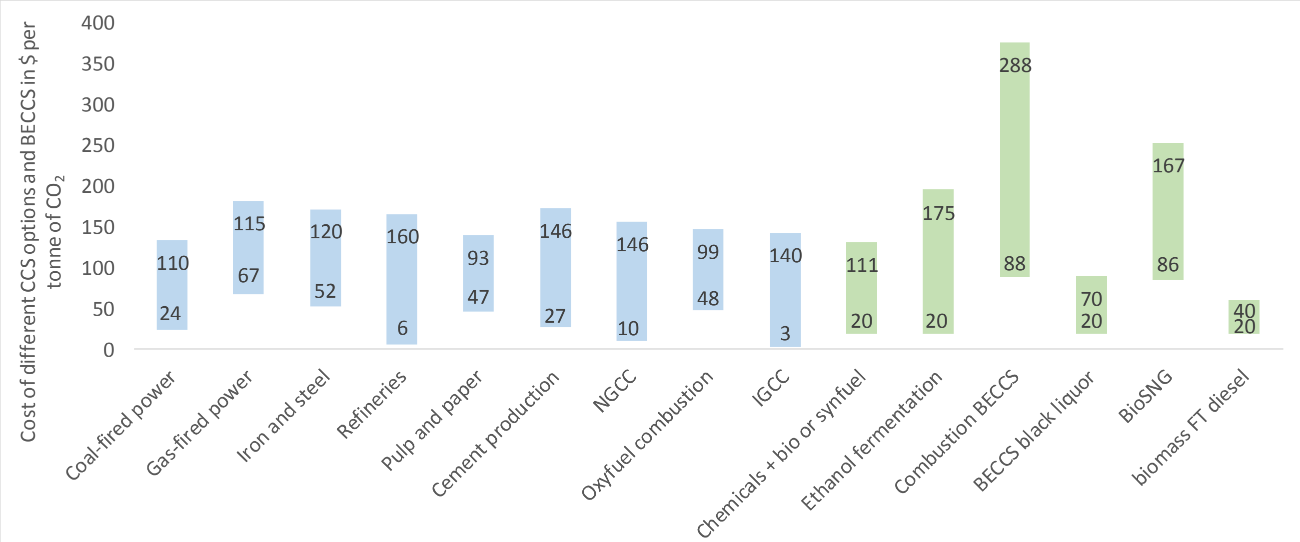

Figure 11 Cost of avoided CO2 emissions of different conventional CCS options compared to BECCS based on (Budinis et al. 2018; Fuss et al. 2018)

Tapping this potential requires however the development of a coherent policy framework which combines instruments and targets from energy policies (such as for example the RED II target) and climate policies (e.g. the development of technological pathways to support the achievement of the 80% and 95% GHG reduction targets).

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4. Conclusions

This report represents a first step to analyse the competitiveness of the advanced fuel pathways investigated in the BECOOL project. It is part of BECOOL WP5, focusses on the environmental and economic sustainability of the BECOOL feedstocks and technology combinations for the production of advanced liquid fuels for transportation purposes. The basis for this assessment is a description of the current market framework for advanced fuels in the EU transportation sector. As described in Chapter 2, the market for advanced fuels is currently shaped by the EU RED and RED II legislation. Most important element is the introduction of a mandatory target for advanced fuels (0.2% of transport energy in 2022, 1% in 2025 and increasing to at least 3.5% by 2030) as well as a double-counting instrument. Depending on the national implementation of the RED II in the EU member states, the double-counting mechanism will increase the economic competiveness of advanced fuels but, it might also downsize the market within the advanced fuel sub target (advanced biofuels might be double-counted towards both the 3.5% target and towards the 14% target).

As it is expected, that the BECOOL advanced fuels might be associated with higher production costs than already developed and established technology pathways such as for example Bioethanol from sugarcane or Biodiesel from vegetable oils, the definition of a "protected sub-quota system" is considered an important instrument for the development of advanced fuels. However, this also means that their potential market will be limited up until the 2030 timeframe. Furthermore, various technologies are suitable to produce advanced fuels (as this term is defined under the RED II framework). Some of these technologies are widely developed and significant production capacities do already exist (e.g. biomethane from organic residues and wastes). Even though, the results from the assessment and benchmarking of the BECOOL advanced fuels is pending and it is too early to draw conclusions regarding the competitiveness of BECOOL advanced fuels within the advanced fuels quota market, some first general conclusions can be drawn from the description of the market framework.

1. The general market for advanced fuels in EU transportation will be limited. Several technology options will compete within a relatively small quota target. The existing alternatives (i.e. other biofuel options in road transport or other GHG offsetting mechanisms in aviation) make it unlikely that a market expansion above the advanced fuels quota is an option for most of the advanced fuel technologies.
2. Considering the competitiveness and, even more important, the installed capacities of production facilities within the EU member states, it seems plausible that a large extent of the currently discussed targets for advanced fuels could be fulfilled by biomethane from residues and wastes. Thus, we can conclude, that the target for advanced fuels envisaged in the RED recast is by itself not appropriate for a specific promotion of the development and market introduction of new technologies and advanced fuel pathways. However, considering the ambitious climate policy goals and the promising potential of BECCS to deliver climate negative technology options, the development of a coherent policy framework combining climate and energy policy instruments might create a new perspective for advanced biofuels in the future.
3. Besides road transport, no binding and mandatory targets do exist for the development of an advanced fuel market. Even though, the RED II includes a multiple crediting approach for the use of biofuels in aviation, alternative aviation fuels compete against several other measures to reduce or offset GHG emissions in aviation.

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