BIKE

BIOFUELS PRODUCTION
AT LOW - ILUC RISK
FOR EUROPEAN SUSTAINABLE
BIOECONOMY

D 3.1

Overview on biofuels production facilities and technologies in Europe

Dissemination level:

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1 Executive summary

In task 3.1. "Overview and technology review of existing biofuels plants in Europe" RECORD performed a technology review for assessing the production capacity, and adopted technologies of the present biofuels production sites operating at EU level. The present report is divided in three parts, focusing on three main aspects of the European biofuels sector: the first part is an introduction to the European regulatory framework and, in particular, to the Renewable Energy Directive and to the recently adopted EU fit for 55 package. In this first part, a brief analysis of the electrification of light vehicles is provided as a crucial driver for the expected development of the EU biofuels market in the next 10 years. The second part provides an overview on the European biofuels market and, in particular, on the biofuels production volumes, methodologies, and consumed feedstock. In particular, this section provide information the annual production, the import and export data, the market trend, and the most consumed feedstock for both renewable diesel, and bioethanol in Europe. A focus is also provided concerning advanced renewable diesel, cellulosic bioethanol, and biomethane considered as advanced biofuels according to the Part A, and Part B of RED II Annex IX. The third part contains a study concerning the existing biofuels production plants operating in Europe, with a particular focus on advanced biofuels production plants, and on current demo-scale plants installed in the EU 28. The section provides an updated list of all biofuels production plants, based on a review of available databases, reports and infographics published from 2019 to 2021.

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2 Introduction to the EU biofuels policy

In 2016, the European Commission published the first version of the package: “Clean Energy for all Europeans”. As part of this package, in June 2018, the EU institutions approved the recast of the Renewable Energy Directive. In December 2018, the revised renewable energy directive 2018/2001/EU entered into force, named as RED II. Compared to the first Renewable Energy Directive 2009/98/EC, where the target for renewable energy consumption was set at 20% within 2030, in the new RED II, the overall EU target by 2030 has been raised to 32% [1]. In this context, biofuels, and in particular advanced biofuels not affecting indirect land use change (ILUC), are expected to play a key role towards the achievement of the target. However the advanced biofuels sector is still at an emerging stage within the EU market, with a reduced number of commercial production facilities and a strong uncertainty concerning the future development. This report provides an overview on the existing market and of most common technologies currently adopted in Europe, in order to support the future studies to be performed within the BIKE project concerning the expected role of Low-ILUC biofuels in the EU transport sector.

2.1 The EU Renewable Energy Directive

In its initial version, the RED 2009/98/EC had set a target of for transportation biofuels to reach 10% of total primary energy consumption in the EU transport sector. However, the total biofuel consumption in Europe in 2010 represented about 4,7% of all transport fuel consumption, but the amount was given mainly by first generation biofuels, typically produced from feedstock cultivated on cropland that was previously used for other agriculture such as growing food or feed. This process is known as **indirect land use change (ILUC)** and it has a direct impact on the carbon footprint of biofuels value chains, negating the greenhouse gas savings that result from increased biofuels consumption. In 2012, the ILUC Directive was integrated to the RED 2009/98/EC. According the ILUC, for the fulfilment of the 10% renewable energy target, the Member States could only count 7% biofuels from food crops. To better address the issue of ILUC in the Clean Energy for All Europeans package, the revised renewable energy directive (RED II) sets a target for biofuels consumption in transport sector to 14% within 2030, **but with strong limits to the consumption of high ILUC-risk biofuels, bioliquids and biomass fuels** with a significant expansion in land with high carbon stock. These limits consist of a freeze first generation biofuels consumption at 2019 levels for the period 2021-2023, which will gradually decrease from the end of 2023. From 31 December 2023 until 31 December 2030 at the latest, that limit of first generation biofuels share shall gradually decrease to 0 %. At the same time, the RED II specifies the biomass feedstock suitable for the production of advanced, low-ILUC risk biofuels. Within the 14% transport sub-target, there is a dedicated target for advanced biofuels produced from feedstocks listed in Part A of Annex IX [1].

Part A and Part B of Annex IX in RED II	
Part A	**Part B**
• Algae if cultivated on land in ponds or photobioreactors • Biomass fraction of mixed municipal waste • Biowaste from private households subject to separate collection • Biomass fraction of industrial waste not fit for use in the food or feed chain • Straw • Animal manure and sewage sludge • Palm oil mill effluent and empty palm fruit bunches • Crude glycerin • Bagasse • Grape marcs and wine lees • Nut shells • Husks • Cobs cleaned of kernels of corn • Biomass fraction of wastes and residues from forestry and forest-based industries • Other non-food cellulosic material • Other ligno-cellulosic material except saw logs and veneer logs	• Used cooking oil • Some categories of animal fats

Figure 1. Feedstocks included in Annex IX of RED II for advanced biofuels production [1].

The contribution of advanced biofuels and biogas produced from the feedstock listed in Part A of Annex IX as a share of final consumption of energy in the transport sector shall be at least 0,2% in 2022, at least 1% in 2025 and at least 3,5% in 2030. The contribution of advanced biofuels in Part B of Annex IX (those obtained from UCO and animal fats) is expected to be limited.

2.2 The Low ILUC biofuels

In summary, supported biofuels will be those defined as “advanced” and “Low ILUC risk”. Low-ILUC risk biofuels are defined as those produced from feedstocks that avoid displacement of food and feed crops through improved agricultural practices (cover cropping, rotation) or through cultivation of areas not previously used for crop production (cultivation of non-food crops on degraded, or abandoned land). The Commission has also adopted an accompanying report on the status of production expansion of relevant food and feed crops worldwide, based on the best available scientific data.

2.3 The EU fit for 55 package

On 14 July 2021, the European Commission adopted the *Fit for 55* package. The Fit for 55 package is the European Commission Work Programme for 2021 aimed at achieving the 55% emission net reduction target by 2030. The fit for 55 package includes a set of new initiatives and amendments to existing regulations and directives influencing the future sustainable development of key economic sectors. The list include 13 cross-cutting legislative proposals, with 8 revisions of existing legislation and 5 brand new proposals [2] . In particular, the following initiatives have been officially started, with the adoption of Fit for 55 package on 14 july 2021 [3]:

- Revision of the EU Emissions Trading System (ETS), including maritime, aviation and CORSIA as well as a proposal for ETS as own resource
- Carbon Border Adjustment Mechanism (CBAM) and a proposal for CBAM as own resource

- Effort Sharing Regulation (ESR)
- Revision of the Energy Tax Directive
- Amendment to the Renewable Energy Directive to implement the ambition of the new 2030 climate target (RED)
- Amendment of the Energy Efficiency Directive to implement the ambition of the new 2030 climate target (EED)
- Reducing methane emissions in the energy sector
- Revision of the Regulation on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry (LULUCF)
- Revision of the Directive on deployment of alternative fuels infrastructure
- Revision of the Regulation setting CO_2 emission performance standards for new passenger cars and for new light commercial vehicles

The recently started amendment to the RED II aims to strengthen the contribution of renewable energies, and of biofuels to the sustainable transition of EU energy and transport sectors. The amendment activity is just started and it could will bring to an update of the Annex IX and to a change in the EU supporting measures, and application criteria for sustainable biofuels development. BIKE project will play a key role, contributing to put in evidence the potential and the sustainability of Low ILUC biofuels value chains for the EU market.

2.4 The BIKE project goal

The overarching goal of the BIKE project is to facilitate the market uptake of European feedstocks with **low ILUC risk** status for use in biofuels, bioliquids and biomass fuels from 2020 to 2030. The work will inform primarily the bioenergy and biofuels but also other bioproduct sectors since there is also a strongly growing trend from biochemicals/ biopolymers and companies from the chemical industry to use certification schemes able to ensure that bio-based feedstocks for biochemicals are in line with the REDII and the common sustainability requirements.

The present activity, performed within the WP3 of BIKE project, aims at reviewing the existing infrastructure and biofuels processing plants now operating in Europe, in order to evaluate the market readiness, and the development status of advanced and low ILUC biofuels sector in Europe. The following paragraphs aims to provide an updated overview on the European Biofuels market and, in particular, on the market development status of low ILUC risks and advanced biofuels.

3 Present and perspectives of biofuels use in the EU transport sector

3.1 Reducing GHG emission of EU transport sector

Transport sector represents one of the most critical challenge towards the achievement of EU emissions reduction. In fact, the GHG emissions produced by transport sector continued to rise since 1990 until almost 2007, before the Renewable Energy Directive managed to set sustainability targets. However, after a reduction from 2007 to almost 2014, greenhouse gas emissions from the EU-28 transport sector have been increasing again [4].

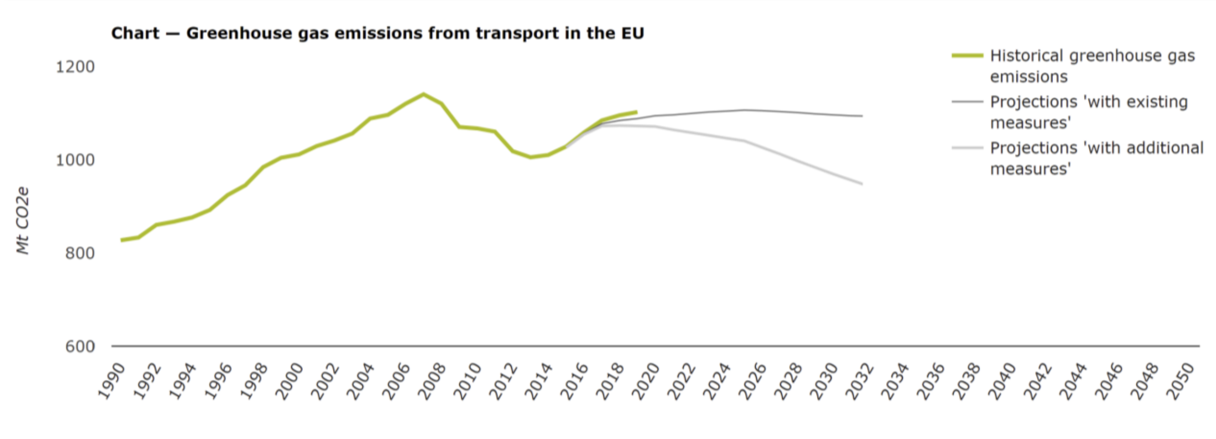

Figure 2. Greenhouse gases emission trend from transport sector in EU (1990-2020). Source: Eurostat 2021

In 2017, transport (including aviation and shipping) was responsible for 27 % of total greenhouse gas emissions produced by the 28 European member states. Of that total, road transport was responsible for almost 72 % of total GHG emissions from transport (including international aviation and international shipping). GHG emissions related to road transport kept also rising from 2017 to 2020, until the global pandemic changed the trend. The largest contribution to the transport sector emission is by far given by cars (about 32%), followed by aviation (13.9%), heavy duty vehicles (13.8%), and maritime transport (13.4%) [4].

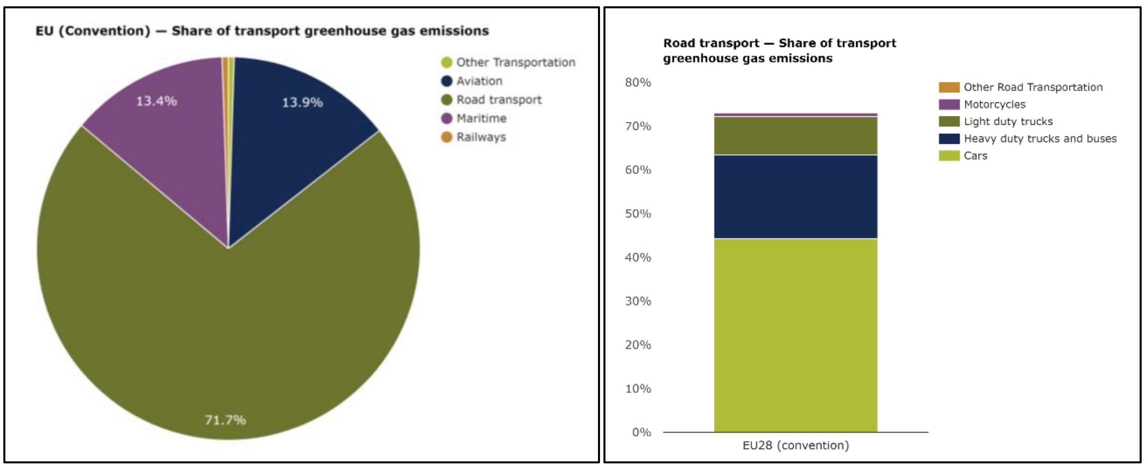

Figure 3. Share of GHGs emission by transport vehicle in Europe in 2019. Source: Eurostat 2021

If aviation sector decarbonization presents more uncertainties and difficulties, the reliability of a sustainable transition for road transport, including light and heavy vehicles, has been largely demonstrated by the use of both biobased fuels and electric engines. In particular, electrification of transport sector represent a key driver also for a reliable biofuels market forecast.

3.2 Present and future contribution of electric vehicles

So far, GHG reduction in transport sector has been achieved only by the use of biofuels, and by improving the energy efficiency of engines, however, a significant contribution is expected from electric mobility. In 2019, according to the European Commission, the use of renewable electricity in road transport has increased substantially, although still constitutes around 1 % of net total energy used in transport [5]. However, despite the present small contribution, the electrification of transport sector, including power to x fuels is estimated to grow quickly in the next years, also thanks to the incentives provided by EU member states. According to [6] both electricity and power-to-x fuels play a key role in decarbonizing the road transport sector, reaching 37% and 27% of total fuel consumption in 2050, respectively. However, this increase in the consumption of electricity for road transport sectors is expected to result in 1200 TWh additional electricity demand in Europe. Additionally, further uncertainties are related to the expected volume of batteries to be produced and, by consequences, of critical raw materials to be consumed for the construction of such a huge number of electric vehicles. It is for this reason that biofuels, if sustainable, could still play a key role in the achievement of 2030 and 2050 sustainability target for transport sector.

3.3 Biofuels use in EU transport sector

In Europe, three main biofuels types have been identified and studied in this report:

3.3.1 Bioethanol

Bioethanol is an alcohol widely produced both for industrial and food sector. First generation, most conventional bioethanol is produced by fermentation and distillation of sugars. Therefore, the most used feedstock are sugar beet, sorghum, sugar cane, but also corn and wheat. Second generation bioethanol is produced by fractionation of lignocellulosic biomass, where lignin, cellulose and hemicellulose are separated, and the cellulosic fraction is then hydrolyzed with enzymes to extract sugars to be distilled into alcohol.

3.3.2 Renewable diesel

Renewable diesel has been identified in this report as a terminology including two different biofuels types:

- Biodiesel: refers to traditional biodiesel, FAME (fatty acid methyl ester), obtained by transesterification of fats (animal fats, used cooking oil, vegetable oils), with methanol.
- HVO: refers to the hydrogenated Vegetable Oil, which is a mixture of paraffinic hydrocarbons obtained by hydrocracking, or hydrogenation of vegetable oils.

3.3.3 Biomethane

Biomethane is the CH4 obtained from any biomass stream processed by the integration of anaerobic digestion and biogas purification (i.e. separation of CH4 and CO2) processes. The biomethane is fully equivalent to the fossil methane currently adopted for ligh vehicles transport, household and industrial thermal energy supply.

As reported in the figure below, the biofuels consumption in EU raised constantly until 2012, when Low ILUC directive was introduced amending the targets of the renewable energy directive. After the decrease occurred from 2012 and 2013, the global production re-started to slightly increase. However, the increase was only partially driven by the take-off of advanced biofuels production. In fact, conventional 1st generation biofuels still represented the largest market portion, and strongly contributed to the growth of biofuels blending until 2019. In 2019, COVID-19, consumption of bioethanol amounted to about 1.4% and renewable diesel (including HVO) reached the 6.4 % of consumed transport fuels in Europe, for a total biofuels consumption of around 7.8%. The rise of bioethanol consumption was slight and almost equal to the level of 2011. In contrast, consumption of biodiesel and HVO has increased.

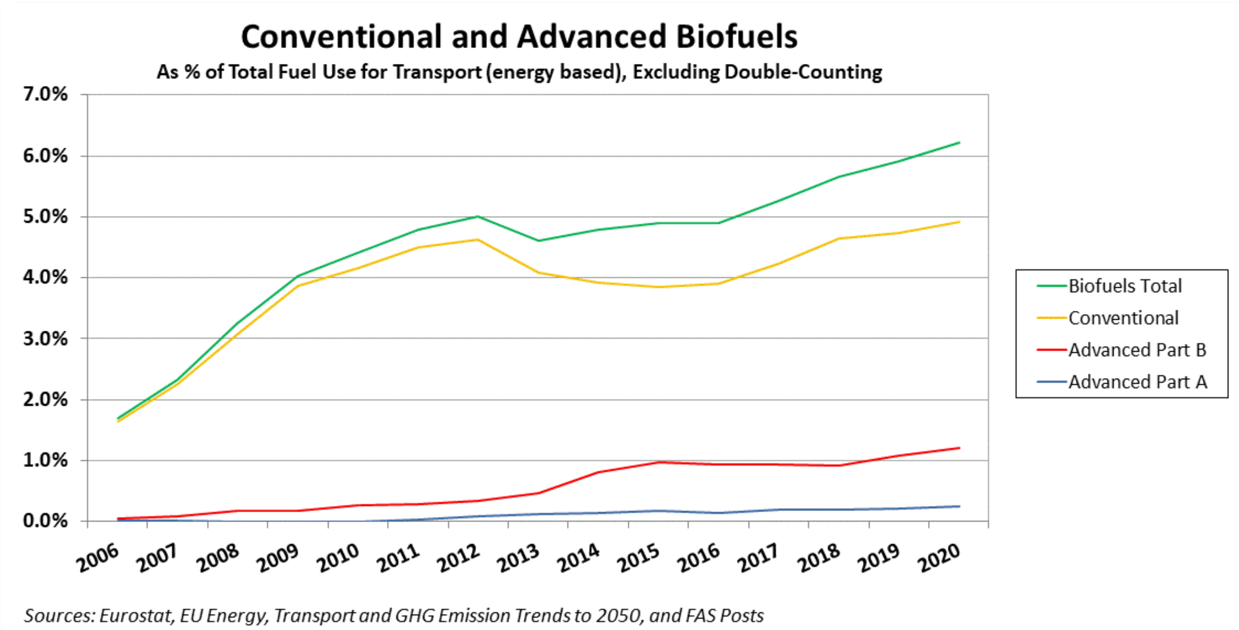

Figure 4. Biofuels blending rate as % of total transportation fuels energy consumption in Europe. Source: EU energy, Biofuels Annual 2020, Eurostat

In 2020, total biofuel blending with fossil fuels (on an energy basis and with double-counting of advanced biofuels) is estimated to reach 8.1%. This is a minor increase compared to the blending of 7.8% achieved in 2019: 3.6% increase for bioethanol and 5.8% for biodiesel and HVO. Blending of conventional (food based) biofuels is estimated at 4.1% - 5%, below the 7% cap set by the ILUC Directive, and for 2021 - 2030 by the RED II. Blending of advanced (non-food based) biofuels is estimated around 1%. The majority of these advanced biofuels blended is represented by biodiesel and HVO produced from waste fats and oils (listed in Part B of Annex IX of the RED), and only a small percentage is produced from agricultural and forestry by-products such as pine oil and cellulosic feedstocks oils (listed in Part A of the REDII Annex IX). Lignocellulosic, or advanced bioethanol contribution to EU biofuels sector is neglectable. The following paragraphs analyse in more detail the present and future contribution of different biofuels type to the EU transport fuels market sector.

4 Market, volumes and trends of biofuels in Europe

At present, biofuels market in Europe is dominated by the conventional biofuels consisting of those obtained by food-based feedstock, also named first generation biofuels. As reported in the paragraphs above, the production and consumption of first generation biofuels have been limited by the European Commission since 2012, with the Low ILUC directive, establishing a cap to the use of these fuels at 5%. The cap is almost achieved and, thanks to the new biofuels supporting measures reported in the RED 2018, the biofuels market is expected to change in the next years. Advanced biofuels production is expected to rapidly grow from 2021 to 2030. However, different trends are expected for advanced biodiesel, thus HVO and biodiesel produced from feedstocks listed in Annex IX, Part A and B, and for advanced bioethanol, represented by lignocellulosic bioethanol. An overview is reported in the paragraphs below.

4.1 HVO and biodiesel production in Europe

Renewable diesel (HVO and biodiesel) total production in EU amounted to about 15.7 – 16.6 million cubic meters in 2019, equal to around 14 million tons (considering biodiesel density of 0.88 g/cm^3) [7,8]. The production volumes raised slowly in the last 5 years, also thanks to the contribution of hydrogenated vegetable oil.

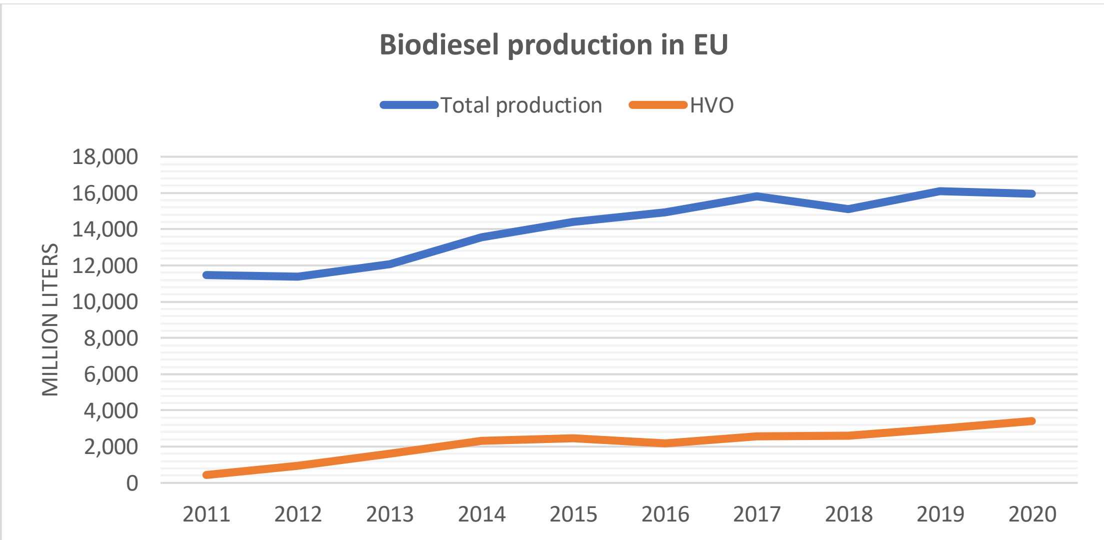

Figure 5. Conventional biodiesel and HVO share on total EU transport sector. Source: Biofuels annual [8]

The most common feedstock consumed for renewable diesel production is rapeseed, excluded from those considered for advanced biofuels production by RED II in the Annex IX. However, the range feedstocks consumed from 2011 to 2019 changed significantly, following the request of the EU renewable energy directive, increasing the amount of biodiesel derived from UCO, decreasing the consumption of high ILUC feedstocks like sunflower, rapeseed, and soybean. On the contrary, palm oil consumption increased.

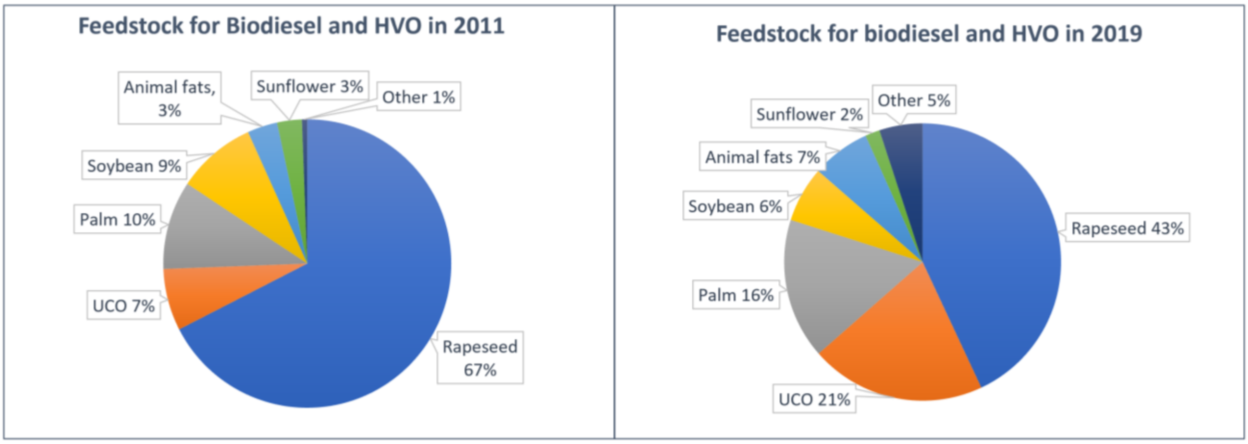

Figure 6. Feedstocks consumption for biodiesel and HVO production in 2011 (a) and 2019 (b). Source: Biofuels annual 2020 [8].

According to [8], rapeseed consumption decreased from around 67% in 2011, to 43% in 2019. On the contrary, UCO passed from 7% to 21%. Palm oil share in the EU feedstock for biofuels production also slightly increased, from 10% to 16%. However, the production of HVO, or biodiesel from palm oil can be considered as "advanced" only in case of Palm oil mill effluent and empty palm fruit bunches are used. The quantities of different feedstocks used in 2019 for biodiesel and HVO production is reported in the table below.

Table 1. Feedstocks share by type for renewable diesel production from 2011 to 2019. Source: IEA bioenergy [7], Biofuels annual[8].

Year	2019
Rapeseed	5.8
UCO	2.7
Palm	2,55
Soybean	0,87
Animal fats	0,9
Sunflower	0,25
Other	0,74

Despite HVO represents an innovative, effective solution for renewable diesel production, this process is not sufficient for labelling the biofuel as sustainable, nor as advanced. On the contrary, the RED II identifies a set of starting feedstock to be used, supported by the EU, for advanced biofuels production. At present, most of the advanced renewable diesel produced in EU is obtained from UCO and animal fats, listed in RED II annex IX, Part B. A neglectable part of renewable diesel is produced from other advanced feedstock.

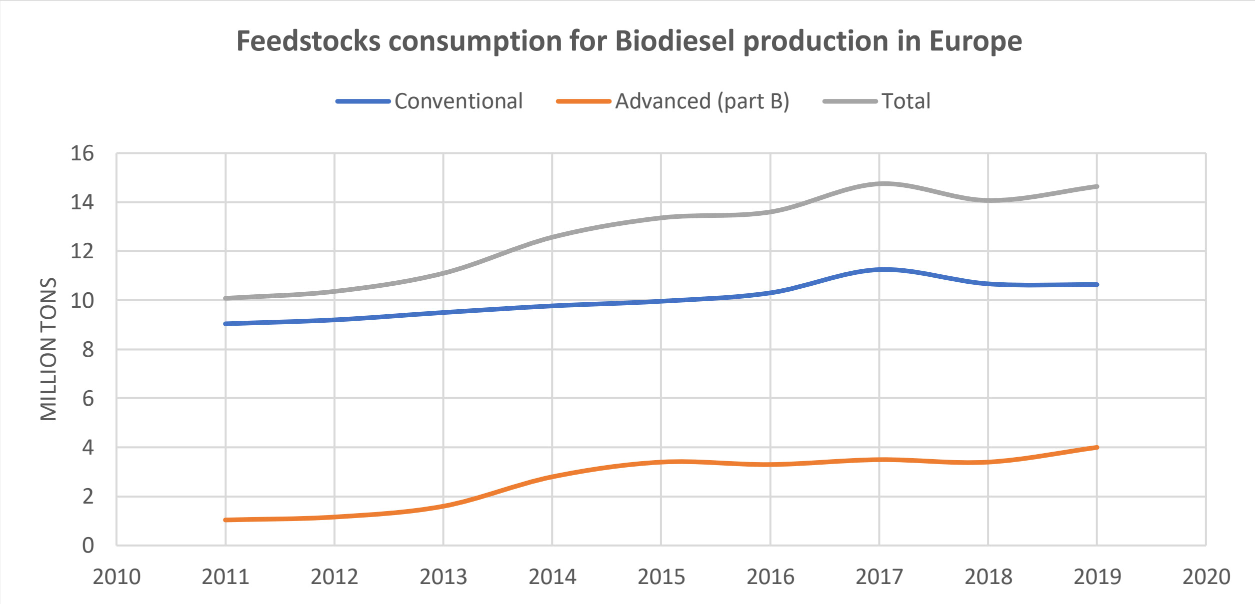

Figure 7. Feedstocks consumption trend from 2011 to 2019 for advanced renewable diesel production in Europe. Souce: Biofuels annual 2020 [8].

4.2 Conventional and Lignocellulosic bioethanol production in Europe

The total production of bioethanol in Europe is annually updated by two organizations: EPure, the association of European ethanol producers the United State Department of Agriculture (USDA). The data of total EU bioethanol production for the year 2019 range from 5,2 [8] to 5,6 million cubic metres [9], before decreasing in 2020 due to covid pandemic. Most of the produced ethanol in Europe is first generation, and comes from Corn, sugar beet, or wheat fermentation. Cellulosic ethanol is produced at demo-scale, for a total estimated amount not greater than 20,000 litres per year.

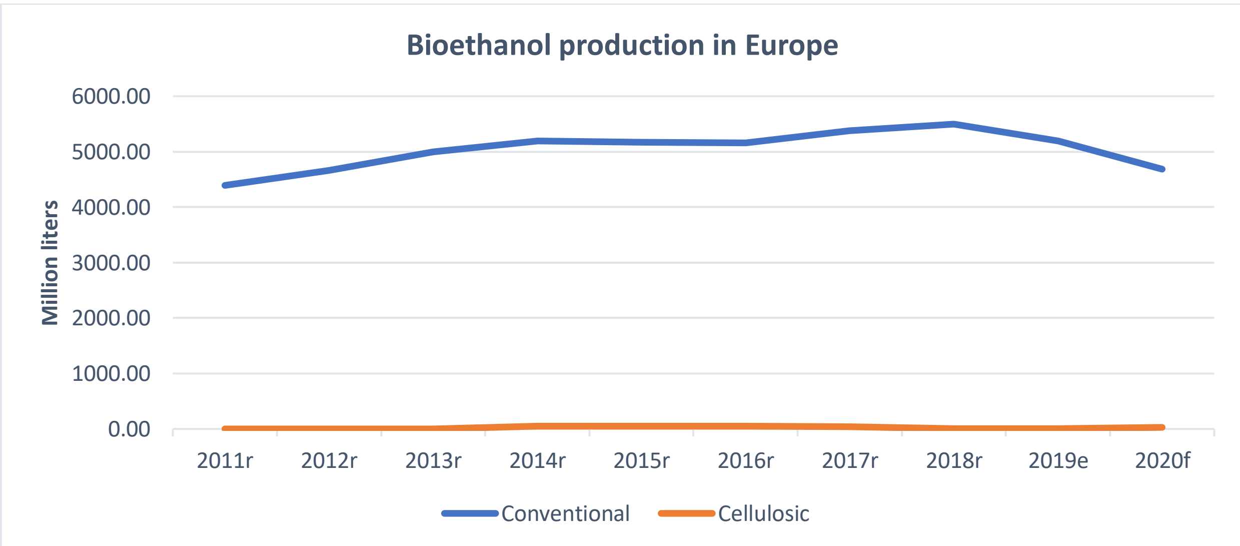

Figure 8. Conventional and cellulosic ethanol production in Europe from 2011 to 2019. Source: Biofuels Annual [8]

Regarding feedstock used for ethanol production, Epure and USDA provide almost equal amounts for all feedstocks apart that for sugar beet. In particular, the below table shows the data feedstocks consumption for bioethanol production in 2019.

Table 2. Feedstocks used for bioethanol production in Europe [8,9].

Year	2019
Wheat	3.1
Corn	6.9
Barley	0.3
Rye	0.4
Triticale	0.8
Sugar beet (sugar Juice)	6.4(1.84)
Cellulosic	0.4

The numbers show that corn is by far the most used biomass feedstock for bioethanol production in EU, followed by wheat and sugar beet. It must be mentioned that sugar juice from sugar beet has a very high ethanol yield and, in fact, the amount of sugar based ethanol in 2019 was almost equal. According to [9], and [8] around 48-50% of the bioethanol produced in EU is obtained from Corn, 19-23% from wheat fermentation, and around 14-19% from sugar beet. A smaller fraction (7-10%) is obtained from triticale, rye, and barley fermentation, and 2-3% is obtained from cellulosic biomass. Below the figure produced by RE-CORD as a result of data assessment from Biofuels Annual Report 2020 and Epure statistics 2020.

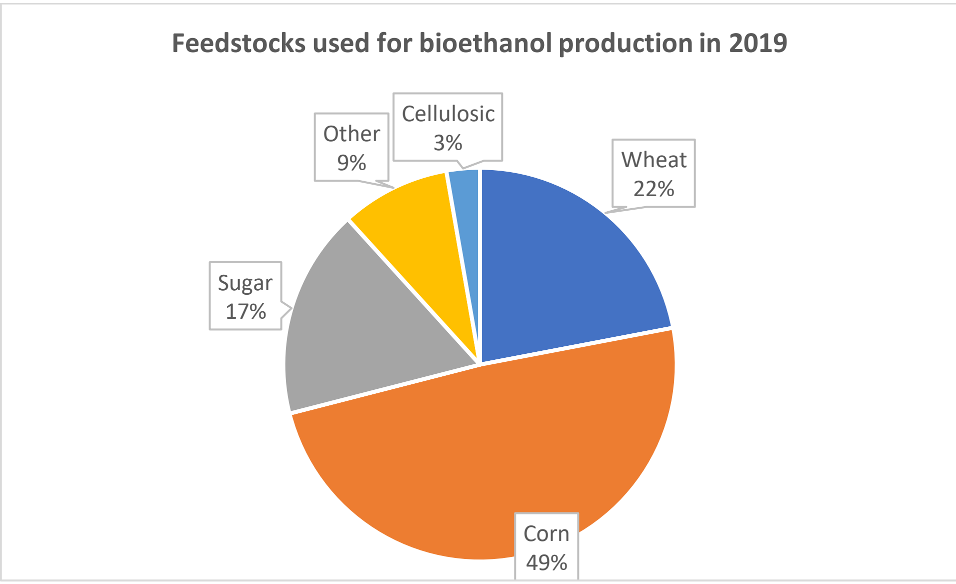

Figure 9. Bioethanol production in 2019 from different feedstocks. (Source: RE-CORD average values, [8,9]).

Cellulosic feedstock for ethanol production achieved a maximum level in 2016, with about 200,000 tons of lignocellulosic biomass converted into bioethanol. However, the capacity reduction and the closure of large demo plants brought to a rapid decrease in the following years. At present, excluding data from 2020, affected by Covid-19 pandemic, the bioethanol market in 2019 demonstrated to be fully based on high ILUC risk production processes processing sugar, corn, and wheat. The below table reports the amounts of raw feedstock consumption from 2011 to 2019

Table 3. Feedstock consumption by type from 2011 to 2019 for bioethanol production in Europe [8].

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019
Wheat	4,46	3,2	3,2	3,3	3,6	3,9	5,2	3,5	3,1
Corn	2,9	4,7	5,1	5,5	5,2	5,1	5,1	6,6	7,0
Barley	0,75	0,4	0,64	0,45	0,41	0,38	0,38	0,49	0,33
Rye	0,69	0,37	0,79	0,82	0,71	0,64	0,50	0,48	0,38
Triticale	0,52	0,72	0,57	0,74	1,03	1,28	0,72	1,26	0,95
Sugar*	9,48	10,6	11,7	11,3	10,0	8,83	8,29	7,53	6,38
Cellulosic	0	0	0	0,20	0,20	0,20	0,16	0,04	0,04

**Calculated amount of feedstock considering the theoretical maximum production of co-products (grain, solid residues) based on estimated feedstock use in fuel ethanol production.*

As visible, the transition of bioethanol market towards the sustainable, low-ILUC targets is still to begin in Europe. Few demo-scale plants demonstrated the operability and the feasibility of advanced ethanol production processes, but so far the market penetration was not economically feasible. The RED II is expected to play a crucial role in the support of advanced bioethanol production volumes in Europe.

4.3 Biomethane and advanced biomethane production in EU

Methane, or natural gas use as transport fuel is growing rapidly thanks to the lower emission of this gas in comparison to gasoline and diesel fuels. The growth of this sector is increasing the potential use of also biomethane as a transport fuel in Europe. According to EBA, around 725 biomethane plants are already in use in Europe, producing around 26TWh of biomethane. The EBA expects that the biomethane overall production will increase to up to 467TWh by 2030, **of which around 117TWh will be available for the road transport sector.** This will allow for an increase in the share of biomethane used to fuel Europe's natural-gas vehicle fleet, which it said will comprise around 13.2 million vehicles by that date.

In comparison, only around 3.9TWh of biomethane was used to fuel natural-gas vehicles on European roads in 2020. By the end of 2019 Europe had 18,943 biogas plants with a combined biogas production of 15.8 bcm. 2019 saw the biggest increase in biomethane plants to date amounting to a production of 2.4 billion cubic metres.

If the sector keeps up with this pace, there is a consensus that by 2030, the biogas and biomethane sectors combined can almost double their production and by 2050, production can more than quadruple. The estimated potential ranges between 34 - 42 bcm (equivalent to 370 - 467 TWh) by 2030. By 2050, the potential is estimated at 95 bcm (1,008 - 1,020 TWh). The EBA strategy for the coming years estimates that the biomethane sector alone will be able to reach a production volume of 34 billion cubic meters by 2030. The below figure reports the growing trend of biomethane production plants in Europe from 2011 to 2019

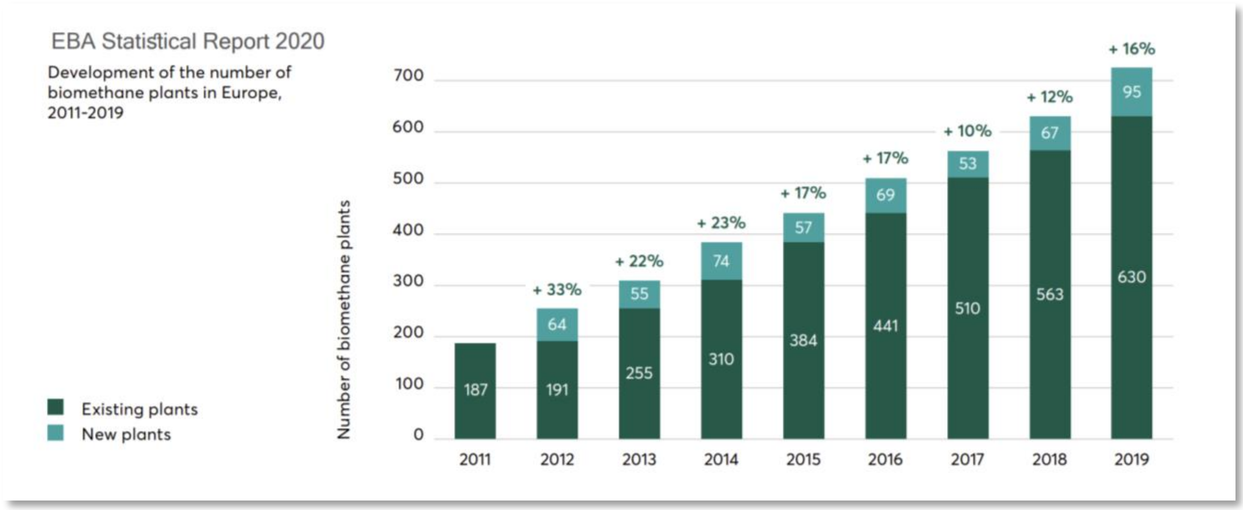

Figure 10. EBA statistical report on biomethane plants in Europe. Source: EBA, 2020

It is interesting to see that, the market growth from 2011 to 2019 of biomethane sector has been incredibly strong compared to other biofuels sectors. According to EBA, the biomethane production from 2011 amounted to about 750 GWh, and in 2012 to around 2100 GWh. These values, if compared to the 26000 GWh of 2021, show an impressive market growth of about 3300% compared to 2011 and 1000% compared on 2012 figures.

5 Import and export of liquid biofuels

5.1 Renewable diesel and HVO

During the last decade, the consumption of renewable diesel in Europe strongly increased, going from 14,3 million cubic metres in 2011 to about 19 million in 2019. This consumption growth was well followed by an increase in the production volumes, enabling to avoid a strong increase of the importation, but to increase the export.

Table 4. Renewable diesel trading in Europe. Source: Biofuels Annual [8].

Renewable diesel market in Europe (million cubic metres)									
Year	2011	2012	2013	2014	2015	2016	2017	2018	2019
Consumption	14,3	14,5	13,1	13,95	14,67	15,15	16,72	17,99	19,14
Import	3,03	3,3	1,34	0,63	0,54	0,63	1,33	3,78	3,64
Export	0,10	0,12	0,42	0,18	0,24	0,41	0,37	0,64	0,77

5.2 Bioethanol

Bioethanol consumption in Europe remained almost stable along the last ten years, passing from 5,7 to 6 million tons from 2011 to 2019. At the same time, the import of bioethanol during the same period strongly decreased, passing from 1,2 million cubic meters to 830.000 cubic metres.

Table 5. Bioethanol trading in Europe. Source: Biofuels Annual [8].

Bioethanol market in Europe (million cubic metres)									
Year	2011	2012	2013	2014	2015	2016	2017	2018	2019
Consumption	5,7	5,67	5,37	5,38	5,40	5,31	5,53	5,93	6,01
Import	1,28	0,88	0,59	0,42	0,23	0,23	0,24	0,48	0,83
export	0,99	0,95	0,63	0,63	0,42	0,28	0,41	0,96	0,53

6 Forecast to 2030

The 2050 projections that focus on the Paris Agreement Goals expect that liquid biofuel demand from all transport modes, excluding international shipping, will be in the range of 1200-1800 PJ. For the aviation sector biofuel demand appears to be in the range of 580-960 PJ.

At present, the contribution of advanced biofuels and, in particular of advanced biofuels listed in Part A of Annex IX is almost neglectable. The mandatory target of the European Commission is to increase the sustainability of the internal biofuels production system, turning from first generation, to advanced liquid and gaseous biofuels in agreement with the new measures proposed by the RED II (2018).

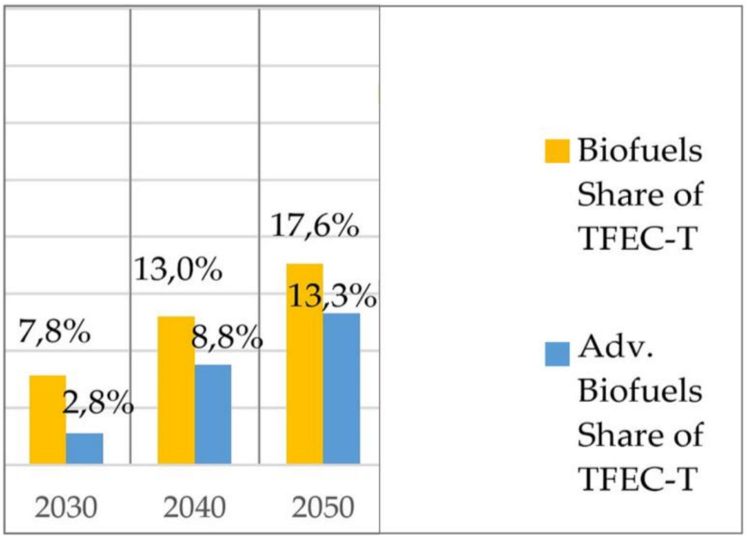

Figure 11. Projections of biofuels and advanced biofuels share of total final energy consumption in the transport sector (TFEC-T), 2021. Source: [10]

The production of conventional biofuels, currently produced from conventional food crops and affecting the indirect land use will be decreasing gradually after reaching the 7% cap established by the Renewable Energy Directive. Similarly, the production volumes of advanced biofuels identified in Annex IX, part B of the directive (those produced from animal fats and UCO) will remain constant, without relevant increase. On the contrary, a rapid, strong increase is expected for advanced biofuels produced from low ILUC, non food crops as listed in the Annex IX, part A of the RED II, considered as the real solution for the sustainable transition of the EU transport sector. According to [10], in the mid scenario, biofuels and advanced biofuels together are expected to contribute to more than 17% by 2050, with advanced biofuel expected to prevail already by 2040.

7 Biofuels production facilities in Europe

This work is intended to provide a review of EU biofuels producing facilities, focusing in particular on liquid biofuels (bioethanol, renewable diesel) and biomethane of first, second and so-called third generation. JRC [11] provides an very useful interactive map of the EU facilities (UK is not included), which analyses also their type of products and feedstock sources. The map includes biorefineries corresponding to a broader or stricter definition, as well as facilities in which the manufacturing of products is integrated with the production of energy from the biomass feedstock. The database built by the JRC reports 2,362 facilities using biomass for product manufacturing, including a wide range of plants, from innovative, recently built biorefineries in which the newest principles of circular economy are applied, to very traditional, decades-old plants obtaining products from biomass.

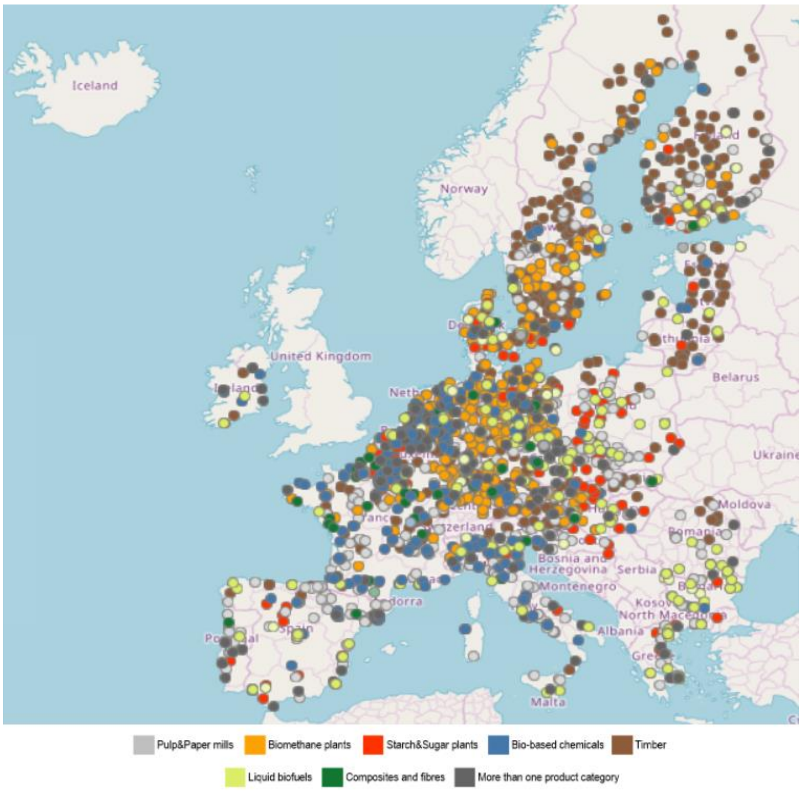

Figure 12. 2,362 facilities using biomass for product manufacturing in EU. Source: JRC, 2020 [10].

Filtering the map according to interest case, i.e. liquid biofuels (from agriculture, forestry, grasses and short-rotation coppice feedstocks) and biomethane, the number of EU facilities amounts to 539, 310 of which are intended for the production of liquid biofuels and 233 for the biomethane production. Maps of liquid biofuels and biomethane production facilities are shown in Figure 13, and Figure 14, respectively.

Figure 13. 310 liquid biofuels production facilities in EU. [10]

Figure 14. 233 Biomethane production facilities in EU. [10]

Another map which identifies biorefineries located in Europe has been developed by BIC (Biobased Industry Consortium) in a study performed in 2017. The map is shown in **Figure 15** and the list of biorefineries is reported in **Annex 1,** sorted by country. The definition of biorefinery adopted in this study by BIC is "an integrated production plant using biomass or biomass-derived feedstocks to produce a range of value-added products and energy". The map does not account biomethane plants. According to the BIC's report, about 224 biorefineries were operating in Europe in 2017, of which:

- 64 Oil/fat-based biorefineries, producing biodiesel or oleochemicals
- 54 Oil/fat-based biorefineries, producing oleochemicals;
- 63 Sugar-/starch-based bio-refineries, producing mainly bioethanol but also products for use in food or feed or biochemical;
- 25 Wood-based biorefineries (excluding pulp for paper only), producing pulp, tall oil, specialty cellulose or bioethanol;

- 5 biorefineries producing cellulosic fibre or bioethanol from other lignocellulosic feedstock such as wheat straw, miscanthus or switch grass;
- 13 biorefineries producing bioethanol or renewable diesel from biowaste (incl. food waste).

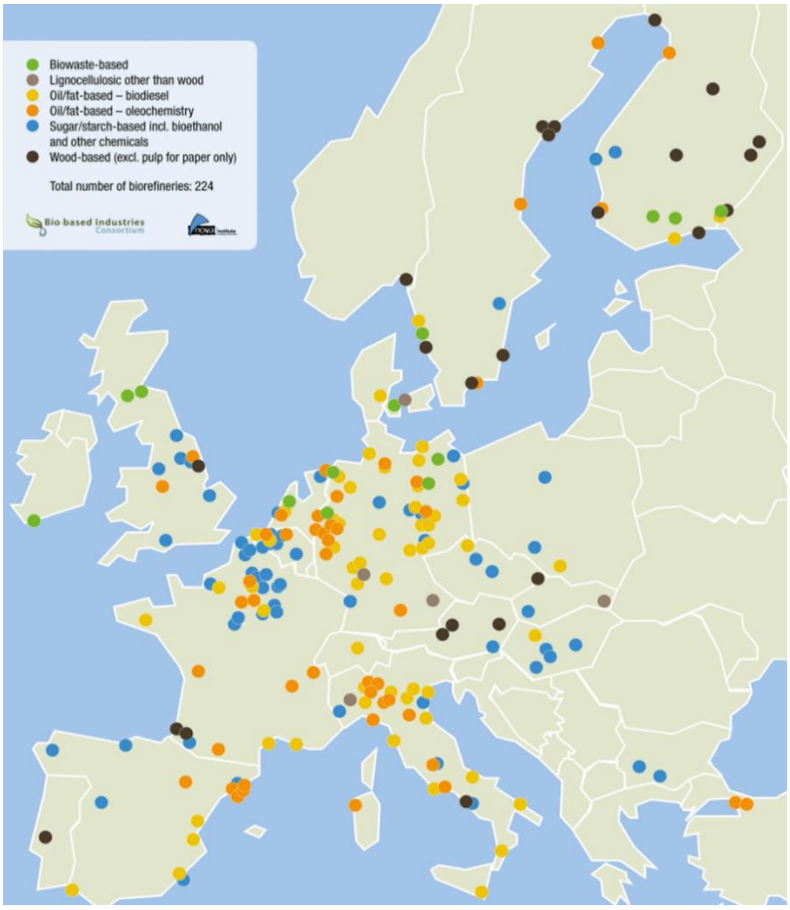

Figure 15. BIC map of biorefineries located in Europe (2017 data). Source: BIC, 2020

The comparison between JRC study and BIC results enables to assess the reliability of the identified data. As BIC does not consider biomethane production plants in its study, the maps shown in Figure 13 and Figure 15 are compared. First, one can notice that the number of biorefineries is quite different: JRC reports 310 facilities, while BIC 224. The reasons of this difference may rely on several reasons, especially considering the definitions of liquid biofuels adopted and the products/feedstocks analysed.
Additionally, it must be considered that the studies refer to two different periods: JRC map is based on 2020 data, while BIC map on 2017 data. Moreover, the study carried out by JRC does not include UK and Norway, while these countries are considered in BIC's report. Biofuels production plants, not shown in BIC report, have been actually identified in Lithuania, and Estonia.

7.1 Bioethanol production facilities in EU

In this section, the state of the art of EU bioethanol production facilities is analysed. The reference year selected is 2019, due to the peculiarity of year 2020, in which biofuels demand, production, supply and refinery products strongly changed. As a matter of facts, in 2020 bioethanol consumption has decreased by about 12.6%, production by 9.8%, and some producers used a portion of their capacity for ethanol-for-transport to produce ethanol-for-disinfectants. By the way, some data referring to 2020 are also included in this report. Information has been mainly gathered in [8].

In 2019, in Europe there were **56 refineries producing first generation fuel ethanol, with a nameplate capacity of 8,8 million cubic meters and a capacity use of 58%, thus producing about 5,1 (5,06) million cubic metres of first generation ethanol per year.** The most used feedstocks are wheat kernels (3,08 million ton), corn kernels (6,9 million tons), barley kernels (0,33 million ton), rye kernels (0,38 million ton), triticale (0,95 million tons), and sugar beets (6,3 million ton).

Additionally, there were 2 refineries producing cellulosic fuel ethanol, characterized by a nameplate capacity of 60,000 cubic meters, but at a capacity use of 17%, **thus producing about 10,500 cubic meters of bioethanol per year**, for an estimated consumption of cellulosic biomass around 40,000 tons.

The total bioethanol production capacity in Europe has been estimated at roughly 8.9 million cubic meters in 2019. Due to the RED II, a further expansion of first generation bioethanol is expected to be limited in favour of advanced biofuels. Information about bioethanol production in Europe is reported below, grouped by country.

Austria

Austria has one bioethanol plant with a capacity of 0,25 million cubic metres. The main feedstocks used are wheat and corn.

Belgium

Belgium has 3 plants which produce bioethanol. The main feedstocks are beet pulp or concentrated juice, but also sugar beets and its derivatives are used.

France

France is the largest producer of bioethanol in the EU. The main feedstock is wheat. Sugar beets are only processed for bioethanol in a few sugar beet processing plants that have on-site ethanol distillation capacity.

Germany

Bioethanol production in Germany is declining since 2019. The main feedstock is wheat, but also sugar beets and its derivatives are used.

Hungary

In Hungary, both capacity and production expanded significantly during the past five years. Fuel grade ethanol is fully corn-based and produced by two plants, each processing about 1,1 MMT of corn. Combined, these plants produce 0,64 million cubic metres of fuel ethanol annually, most shipped to other EU countries.

Netherlands

The main ethanol plant in the Netherlands is located in the port of Rotterdam. Using 1,2 MMT of feedstocks each year, it can switch between wheat, corn, barley and sorghum. Since 2013, the plant has mainly operated using corn, which boosted Dutch imports from the Ukraine.

United Kingdom

Bioethanol production capacity in UK is estimated at 0,00113 billion cubic metres, considering that two plants are operating but at a lower production level. The main feedstock is sugar beets and its derivatives. Wheat is manly used, but also corn. Ethanol plants are located at seaports. In 2019, UK produced 0,38 million cubic metres of fuel bioethanol.

Table 6. Bioethanol production in Europe (2019 data). Source: Biofuels Annual 2020

Country	Capacity [million cubic metres]	Feedstocks
Austria	0,24	wheat, corn
Belgium	0,62	beet pulp, concentrated juice, sugar beets and its derivatives
France	1,08	wheat, sugar beets
Germany	0,69	wheat, sugar beets and its derivatives
Hungary	0,645	corn
Netherlands	0,57	wheat, corn, barley and sorghum
Poland	0,286	straw
Spain	0,55	corn
UK	0,38	sugar beets and its derivatives, corn
Total	**5,06**	

7.2 Biodiesel & HVO production facilities in EU

In this section, the renewable diesel facilities producing both biodiesel and HVO in Europe are reviewed, with reference to year 2019.

In Europe, there are 187 biorefineries producing renewable diesel (2019), characterized by a nameplate capacity of 21,3 million cubic meters and a capacity use of 61.4%, **thus producing about 13,1 million cubic meters**. Additionally, there are 15 biorefineries producing renewable diesel (HVO), with a nameplate capacity of 5 million cubic meters and a capacity use of 59.1%, **thus producing about 3 million cubic metres**.

EU renewable diesel production plants (FAME and HVO) are characterized by an average annual capacity which spans from 0,023 million cubic metres to 0,68 million cubic metres.

The production of HVO in Europe is performed only in seven EU countries and, thanks to the establishment of new plants in Italy and France, has increased by 47% in 2019.

The production of FAME in Europe is carried out in every Member State, except for Finland, Luxembourg and Malta, and has increased by 0.5% in 2019 as a result of expansions in countries like Greece and Poland. Europe produced 13,11 million cubic metres of FAME and 2,99 million cubic metres of HVO in 2019. Information about renewable diesel production in EU countries is summarized in Table 7.

Table 7. Renewable diesel (HVO and FAME) production in Europe (2019 data). Source: [8]

Country	Biofuel	Capacity [million cubic metres]
Finland	HVO	0,385
France	FAME	2,556
France	HVO	0,128
Germany	FAME	3,862
Italy	FAME	0,511
Italy	HVO	0,451
Spain	FAME	1,835
Spain	HVO	0,549
Poland	FAME	1,091
Portugal	HVO	0,037
Netherlands	FAME	1,079
Netherlands	HVO	1,218
Sweden	HVO	0,218
UK	FAME	0,51
Other	FAME	1,669

Portugal and Spain host large scale HVO plants, but the produced biofuel can't be considered as "advanced" according to the Annex IX, as the feedstock used is Palm Oil. In Portugal, GALP owns a HVO plant in Sines, operating since 2017. The annual production capacity of the plant is 0,04 million cubic metres. In Spain, 7 plants producing HVO are present. The companies producing this advanced biofuel are CEPSA (from 2011) and REPSOL (from 2013) with a total capacity is 0,945 million cubic metres per year. CEPSA owns one operational plant in La Rabida (50000 t/year capacity) and another operational plant in San Roque (50000 t/year capacity).

The main feedstocks used in EU renewable diesel production plants are:

- *Rapeseed oil*
  In 2019, 43% of feedstocks used for renewable diesel production in EU was represented by rapeseed oil, which means that 6,3 MMT of this kind of oil has been used to produce renewable diesel. Its percentage in the feedstock mix is decreasing since 2008 (72%), because

of the higher use of recycled vegetable oil/UCO and the competition with the cheaper imported feedstocks, e.g. palm and soybean oil;

- *UCO*
  In 2019 2,99 MMT of UCO has been used as feedstock for renewable diesel production (21% of total feedstock usage). UCO benefits of double-counting in EU countries like Austria, Belgium, Croatia, France, Hungary, Ireland, Netherlands, Poland and UK;
- *Palm oil*
  Palm oil represents the 16% of the feedstock mix (2019), and is mainly used in Italy, Span, France, Netherlands and lesser extend in Finland, Germany and Portugal. Negligible amounts are used in Romania, Greece, and Poland. In 2019 2,41 MMT of palm oil have been used for renewable diesel production;
- *Soybean oil*
  Together with palm oil, its usage in conventional biodiesel is limited by the EU biodiesel standard DIN EN 14214 and colder weather conditions. Main users are Spain, Germany and the Netherlands, and, in smaller amounts, France, Belgium, Portugal, Romania, Italy, Austria and Greece. In 2019, 0,95 MMT of soybean oil has been used for renewable diesel production;
- *Animal fats*
  This feedstock profited in lesser extent from double counting with respect to UCO, as only few countries (Denmark, Finland, France, Netherlands and UK) include it in this kind of mechanism. In 2019 Italy was the country using the largest amount of animal fats for producing renewable diesel, followed by Netherlands and France. Other countries like Finland, UK, Germany, Denmark, Spain, Austria, Ireland, Hungary and Poland use this feedstock as well, but in lower amounts. In 2019, 1 MMT of animal fats have been used for renewable diesel production;
- *Sunflower oil*
  It accounts for only 1% of total renewable diesel feedstock, and is principally used in Greece, France and Bulgaria. In 2019 0,245 MMT of sunflower oil has been used as feedstock for producing renewable diesel;
- *Others*
  This type of feedstock includes pine oil and wood (mainly used in Sweden), tall oil (Finland), fatty acids (Germany and Finland), and cottonseed oil (Greece). In 2019 0,738 MMT have been used for biodiesel production.

7.3 Biomethane production facilities in EU

According to [12], the number of biomethane plants in Europe has increased from the 483 plants (2018) to 729 units (2020). 18 countries are currently producing biomethane in Europe. Germany has the highest share of biomethane plants (232), followed by France (131) and the UK (80). A very detailed map of biomethane production plants is provided by [13], which gives info about the location of biomethane production facilities, the production capacity, the main substrates used and the upgrading process.

8 Advanced Biofuels production facilities in Europe

In this part, production facilities for advanced biofuels production in Europe are analysed. Information has been mainly collected from [8], [14], and [7].

Country	Advanced Biofuel	Capacity [million cubic meters/year]	Feedstocks
Finland	HVO	0.115	Tall oil
	HVO	0.43	Oils and fats
	Cellulosic Ethanol	0.01	Saw dust
France	HVO	0.64	Oils and fats (50% palm oil)
Italy	HVO	0.965	Used vegetable oils, animal fats, algae, and byproducts
	HVO	0.465	Palm oil, palm oil by-products, other oils and fats
	Cellulosic Ethanol	0.032	Biomass
Netherlands	HVO	1.28	Oils and fats
	Methanol	0.075	Biogas
Portugal	HVO	0.04	Palm oil
Spain	HVO	0.945	Palm oil
Sweden	HVO	0.22	Tall oil
	Methanol	0.006	Pulp mill side-streams

A map showing EU advanced biofuels facilities (HVO, diesel-type hydrocarbons, cellulosic ethanol, ethanol, gasoline-type fuels) is shown Figure 16, which indicates also the number of plants for each product in each country. Details about the technologies, feedstocks, status and locations of the plants are reported in the next paragraphs.

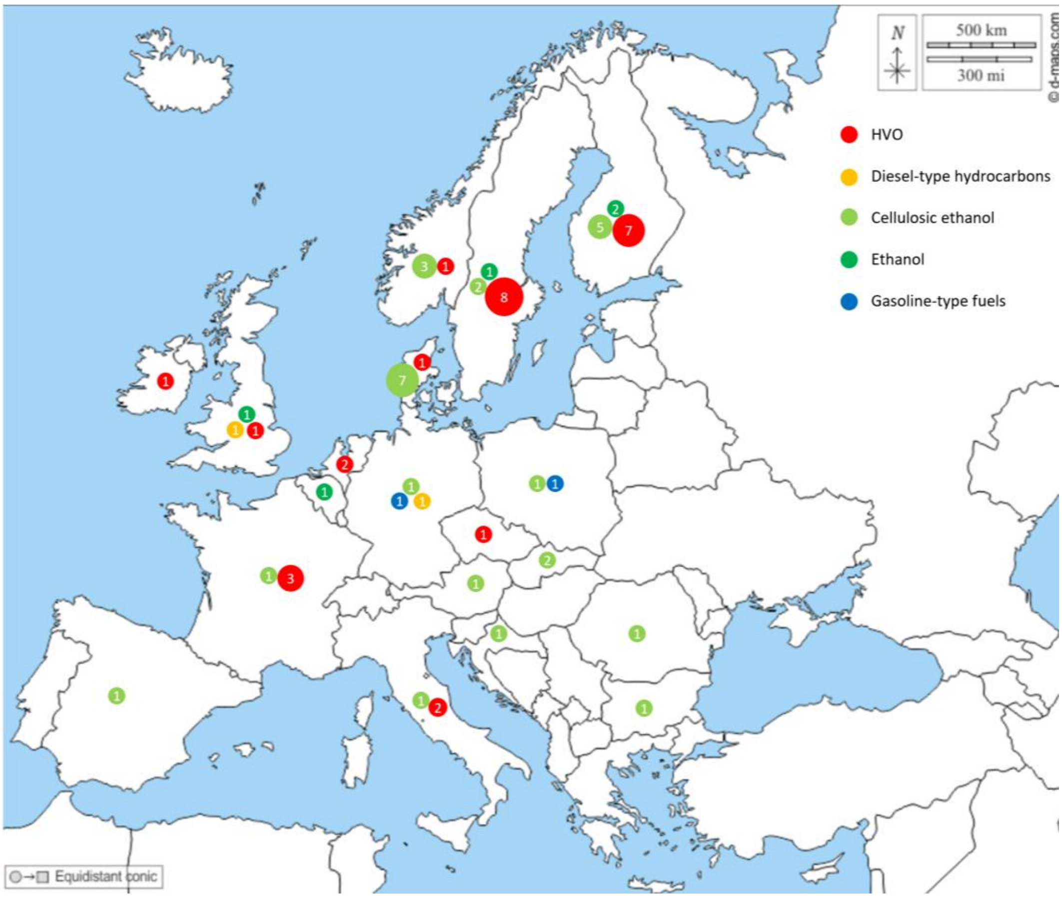

Figure 16. Map of advanced biofuels plants distributed in Europe. Source: [7,8]. Created by RE-CORD

8.1 Hydrogenated Vegetable Oil (HVO) from feedstocks listed in Annex IX

Hydrotreated Vegetable Oils (HVO) are produced via hydroprocessing of oils and fats, which is an alternative process to esterification to produce diesel from biomass. These biofuels are commonly referred to as renewable diesel and Hydroprocessed Esters and Fatty Acids (HEFA), and can be produced from a wide variety of feedstocks containing triglycerides and fatty acids, including low quality waste and residual materials [15]. Below, information on the EU production of HVO is analysed, sorted by country.

Czech Republic

In Czech Republic, the company Unipetrol RPA produces HVO at an experimental scale of roughly 3,200 cubic meters per year.

Denmark

An example of HVO production facility in Denmark is the Steeper pilot plant in Aarhus. It is a continuous pilot facility, located at the campus of Aalborg University, and is in operation since 2013. The pilot plant has demonstrated the Hydrofaction™ technology, which is Steeper Energy's proprietary implementation of hydrothermal liquefaction, which applies supercritical water as a reaction medium for the conversion of biomass directly into a high-energy density renewable crude oil, referred to as Hydrofaction™ Oil. The process is claimed to utilize a wide-range of biomass feedstocks (forestry and agriculture residues, energy plants/crops, industrial food processing, sugar refining, oil seed milling, production wastes from alcohols or ethanol, urban source separated wastes, animal manures or bio-solids, i.e. sewage sludge, and aquatic biomass, etc.) and to process feedstocks as-harvested without the requirement of pre-drying.

Finland

There are several HVO plants in Finland processing animal fats, UCO, as well as other feedstock listed in RED II, Annex IX, part A.

Neste owns a couple of operational plants in Porvoo, i.e. Porvoo 1 and Porvoo 2, each characterized by a production capacity of 190,000 t/year and using the technology of hydrotreatment. The feedstocks are oilcrops, oils and fats.

Additionally, Neste owns another plant in Naantali, with a production capacity of 40,000 t/year which uses tall oil as feedstock. The plant is currently not coperational.

Another plant is owned by UPM and is located in Lappeenranta. The technology adopted is also here the hydro-treatment provided by Haldor Topsoe to obtain HVO, the annual production capacity is 0,115 million cubic metres and the starting feedstock is tall oil. Crude tall oil is a natural extract of wood, mainly from conifers, and is gained as a result of the separation process of fibrous material from wood. It is a residue of pulp manufacturing. Crude Tall Oil is part of Annex IX, part A and therefore classified by the European institutions as residue and eligible for double-counting and is part of the sub-target for advanced biofuels. In Lappeenranta, a significant part of this renewable raw material comes from UPM's own pulp mills in Finland.

UPM is also planning to open another plant in Kotka with a capacity of about 0,55 million cubic metres. The targeted feedstocks are forest by-products, such as saw dust and branches, and oil from the Brassica carinata crop grown in South America.

In 2020, the Green Fuel Nordic Oy partnered with BTG, a Dutch company, to produce 0,025 million cubic metres of pyrolysis oil in 2020 at its plant in Lieksa.

Other companies, which are planning to erect advanced biofuel plants in Finland, are: Nordfuel, BioEnergo, and Fintoil.

The Fintoil's plant, located in Hamina, is planned to produce 0,1 million cubic metres of HVO using oilcrops, oils and fats as feedstock.

France

Total owns one HVO plant (operational) located in La Mede, and one (planned) in Grandpuits-Bailly-Carrois. The first plant plant has a maximum capacity of 0,64 million cubic metres per year and adopts the hydrogenation technology. The feedstocks processed are oils and fats (50 % palm oil, but also sunflower, soybean and carinata. Vegetable oils will comprise 60-70% of the feedstock, while the remaining will comprise treated waste including animal fats, cooking oil, and residues [16].

The plant in Grandpuits-Bailly-Carrois will use the hydrotreatment technology to produce 120,000 t/year of HVO from oilcrops, oils and fats.

Moreover, in France, a cooperation of Avril, Axens, CEA, IFPEN, ThyssenKrupp and Total are working on the *BioTFuel project*, which aims to produce 0,23 million cubic metres of advanced renewable diesel and bio-jet fuel per year from one MMT of biomass. The demonstration-scale plant is located at *Total*'s former Flandres refinery in Dunkerque.

Italy

ENI owns two operational plants, one in Venice and one Gela, both using the technology of hydrogenation.

The plant in Venice is in operation since 2014. The annual production capacity is about 0,325 million cubic metres and is forecast to increase to 0,54 million cubic metres in 2021. The feedstocks used are palm oil, palm oil by-products and other oils and fats, whose proportion is planned to be increased.

The other ENI plant in Gela (Sicily) is a reconverted plant, whose reconversion started in April 2016, to enter in production in August 2019. The plant has a capacity of 0,77 million cubic metres.

Netherlands

Neste owns a HVO plant in Rotterdam, operating since 2011, characterized with an annual production capacity of 1,28 million cubic metres. The technology adopted is hydrogenation and the feedstocks used are waste fats and oils (about 80% of the feedstock used), i.e. palm fatty acid distillate (PFAD), bleaching earth oil, technical corn oil, and animal fats. Planning to reach a 100% waste and residues share by 2025. An expansion of the plant is planned.

Norway

In Norway, some studies have been carried out with regards the upgrading of a wide variety of wastes and residues to HVO. In particular, the Project SILVA GREEN FUEL is an interesting example in this matter. Silva Green Fuel is a joint venture between Statkraft and Sødra for the development of advanced biofuels. The construction of a EUR 50.6M demonstration plant was completed in 2019 at the Statkraft Tofte site, a former pulp mill. The facility utilises Steeper Energy's hydrothermal liquefaction technology (HydrofactionTM) to convert forest residues into a bio-crude oil at a rate of 4 cubic metres per day. The goal is to upgrade the bio-crude oil to produce renewable diesel, jet or marine fuel. After a 2-year validation period, the plant should officially open in 2021, potentially leading to a future commercial scale operation by 2025 [12].

Sweden

In Sweden there are several HVO plants. Preem owns two plants in Gothenburg, whose projects name are Preem HVO 2015 and Preem HVO diesel and biojet. The first one is operational and has a production capacity of 800000 t/year, uses the hydrotreatment technology and oilcrops, oils and fats as feedstocks. The second plant is planned to have a production capacity of 1300000 t/y and use the same feedstocks and technologies of the first one.

Moreover, Preem is investing in another plant in Lysekil, whose name is Preem Revamp Synsat unit, whose production capacity would be 1300000 t/year, and would use the Haldor Topsoe's HydroFlexTM technology to convert oilcrops, oils and fats into HVO. The Finnish company St1

invested on a HVO plant in Gothenburg, which will be in operation in 2022. The plant produces also jet fuel, has a capacity of 0,25 million cubic metres, and will use mostly UCO and tall oil as feedstocks. The company is also planning to build another plant with a capacity of 0,5 million cubic metres of biofuels per year.
SunPine has two operational plants in Pitea, i.e. SunPine HVO 100 mio litres and SunPine HVO addition, whose production capacity is 77,000 t/y and 39,000 t/y respectively. Both use the hydrotreatment technology and use forest residues as feedstocks.

Additionally, the project Project SCA Biorefinery Östrand AB involves a plant in Östrand with a production capacity of 200,000 cubic metres per year, using organic residues and waste streams as feedstocks. Besides, Pyrocell is planning to increase its production capacity.

UK

In UK Greenenergy plans to build a plant in Corrigham, which uses the hydrotreatment technology.

8.1.1 Other diesel-type hydrocarbons facilities in Europe

Germany

In Germany there is one idle plant located in Oberhausen, whose production capacity is 2 t/y and which uses oilcrops, oils and fats as feedstocks.

UK

KEW Technology Ltd is currently constructing a plant in Wednesbury, which employs the gasification technology.

8.2 Advanced bioethanol facilities in Europe

The European Commission Renewable Energy Directive categorizes advanced and non advanced biofuels on the basis of the starting feedstock, and not on the production technology. Therefore, advanced bioethanol can be produced by lignocellulosic biomass fractionation, followed by enzymatic hydrolysis and fermentation process (cellulosic ethanol), by gas fermentation, or by conventional sugar fermentation process. However, most of the feedstock listed for advanced biofuels production in Annex IX, part A of the RED II are lignocellulosic residues, or solid waste streams. Therefore, cellulosic ethanol production route represents now the most common solution for advanced bioethanol production in Europe.

8.2.1 Cellulosic ethanol production facilities

Although chemically identical to first generation bioethanol, cellulosic ethanol is produced from lignocellulosic feedstocks, i.e. agricultural residues (e.g. straw, corn stover), other lignocellulosic raw materials (e.g. wood chips) or energy crops (e.g. miscanthus, switchgrass), which are more abundant and generally considered to be more sustainable. Cellulosic ethanol production plants in Europe are reported below, grouped by country.

Austria

In Austria, in Hallein, there is one operational cellulosic ethanol production plant, owned by the cellulose-producing company AustroCel. The feedstock derives from the remainders of cellulose production of the same company, with capacity is 30,000 t/year. The technology employed is fermentation.

Bulgaria

Eta Bio planned to build a plant using the technology of fermentation to convert agricultural residues to cellulosic ethanol, with a production capacity of 50,000 t/y.

Croatia

INA planned to build a plant in Sisak with a production capacity of 55,000 t/y, which uses the technology of fermentation to convert agricultural residues to cellulosic ethanol.

Denmark

Ibicon (DONG Energy) has planned the construction of several plants, which has been then cancelled. These are Pilot 1 (production capacity of 2 t/y), Pilot 2 (production capacity of 1 t/y), both located in Fredericia, and Demo (production capacity of 4300 t/y), located in Kalundborg. The facilities were planned to use the technology of fermentation and lignocellulosics as feedstock.

Other plants, owned by BornBioFuel, have been cancelled, one located in Ballerup (production capacity of 1 t/y), and the other in Aakirkeby, Bornholm (production capacity of 4000 t/y). The facilities were planned to use the technology of fermentation and lignocellulosics as feedstock.

Another plant, i.e. BioGasol - Maxifuel, was planned to work in Copenhagen using the technology of fermentation and lignocellulosics as feedstock, but it was stopped while under construction. Its production capacity was 10 t/y. RE Energy is planning the construction of a plant in Kalundborg, which uses the technology of fermentation and lignocellulosics as feedstock. No information about outputs are currently available.

Finland

St1 is developing several projects, which involve three plants, all using the technology of fermentation and forest residues as feedstock. The operational plant is located in Kajaani and has a production capacity of 8000 t/y, while the other two are planned both with a production capacity of 40000 t/y and located in Kajaani and Pietarsaari. Additionally, there is an operational plantin Oulu, owned by Chempolis Ltd., with a production capacity of 5000 t/y, which uses the technology of fermentation and lignocellulosics as feedstock.

Kanteleen Voima plans to open a plant in Haapavesi with a production capacity of 65000 t/y, using forest residues as feedstock and the fermentation technology. In Finland, St1 owns two operational bioethanol plants, both employing the technology of fermentation and using organic residues and waste streams as feedstocks. One plant, namely Etanolix Vantaa, is located in Vantaa and has a production capacity of 1000 t/y, while the other one, i.e. Bionolix Hameenlinna, is located in Hameenlinna and has a production capacity of 800 t/y.

France

In France there are two plants producing cellulosic ethanol, both operational and using the fermentation technology. One plant is owned by IFP, is located in Bucy-Le-Long, has a production capacity of 10,000 cubic metres/year and uses agricultural residues as feedstock. The other plant is owned by ARD, has a production capacity of 100 cubic metres/year, is located in Pomacle, and uses lignocellulosic biomass as feedstock.

Germany

A German operational cellulosic ethanol production facility is the Clariant development plant, in Straubing. The plant is meant for the production of cellulosic ethanol from agricultural residues. The key technologies used are: chemical-free steam pre-treatment, integrated on-site enzyme production, hydrolysis, solid-liquid separation, fermentation of C5/C6 sugars to ethanol, and ethanol purification. The plant, which is precommercial, produces up to 1,000 metric tons of cellulosic ethanol every year [17].

Italy

In Italy there is one operational bioethanol plant, based in Crescentino, and owned by Versalis/ENI. The plant has a production capacity of 40,000 t/year [18]. The technologies adopted in the plant are biomass-to-liquid (biochemical conversion), the plant uses the *PROESA®* proprietary technology, which converts biomass into second-generation sugars and then produces biofuels or potentially other chemical bio-intermediates. The PROESA technology utilizes heat treatment followed by enzymatic hydrolysis for pretreatment of the feedstocks. This plant was the first EU plant, and the first on a global scale to produce cellulosic ethanol. The plant uses organic residues and waste streams as feedstocks.

Norway

Borregaard owns two plants in Sarpsborg, both operational and using the technology of fermentation and lignocellulosics as feedstock. One plant has a production capacity of 100 t/y, while the other 15800 t/y. Moreover, a paper mill in Follum is planned to be integrated, during 2021, into an ethanol plant with a capacity of 0,05 million cubic metres. The plant will apply the Cellunolix® technology and will use forest residues as feedstock.

Poland

ORLEN Poludnie (part of ORLEN GROUP) plans to build a plant in Jedlicze with a production capacity of 25000 t/y. The plant uses the technology of fermentation and lignocellulosics as feedstock

Romania

Clariant has started construction of a commercial sized cellulosic ethanol plant in Romania. The announcement was made September 2018. Production capacity is 50,000 tonnes per year. The by-products from the process will be used for the generation of renewable energy with the goal of making the plant independent from fossil energy sources. The resulting cellulosic ethanol is therefore an advanced biofuel that is practically carbon-neutral.

Slovakia

Energochemica owns a plant in Slovakia, which is currently under construction. The plant has a production capacity of 55000 t/y and uses agricultural residues as feedstock. Additionally, a plant in Leopoldov is planned to be operative, owned by Enviral. The plant has a production capacity of 50000 t/y and uses lignocellulosics as feedstock. Both plants use the technology of fermentation.

Spain

Sainc Energy Limited plans to open a plant in Cordoba with a production capacity of 150000 t/y, using lignocellulosics as feedstock and fermentation as main technology.

Sweden

In Sweden there are two operational plants, both located in Ornskoldsvik and using fermentation as main technologu. One plant is owned by Domsjoe Fabriker, has a production capacity of 19,000 t/y and uses organic residues and waste streams as feedstocks. The other plant is owned by RISE Research Institutes of Sweden AB, uses lignocellulosics as feedstock and has a production capacity of 160 t/y. In Sweden, St1 owns one operational plant, namely Etanolix Gothenburg, which produces 4000 t/y of ethanol and is located in Gothenburg. The feedstocks processed are organic residues and waste streams, and the technology employed is fermentation.

UK

Ineos Bio planned the construction of a plant in Tees Valley, but its construction was stopped. The production capacity was 150000 t/y, the feedstocks organic residues and waste streams, and the technology employed fermentation.

8.2.2 Alternative advanced ethanol production facilities in Europe

Advanced ethanol production facilities in Europe are here reported and analysed, sorted by country.

Belgium

In Belgium there is one plant under construction that produces bioethanol, located in Ghent and owned by ArcelorMittal. The technology employed is fermentation, while the production capacity is 62000 t/y, using waste gases as feedstock.

8.3 Advanced Biomethane facilities in Europe

The identification of advanced biomethane production facilities has been performed considering the feedstocks listed in Annex IX of the RED II (See figure 1). However, it must be underlined that most of biomethane produced in Europe is currently injected into the gas grid, or used for energy purposes, and not as transportation biofuel. The entering in force of of RED II is expected to push the use of advanced biomethane for light and heavy duty vehicles. Below, EU advanced biomethane production plants are reported. The main information has been gathered in [14].

Austria

In Austria there is a biomethane production facility, namely Biomass CHP Güssing, which produces biomethane via gasification.

The plant, located in Güssing (AT), is a Combined Heat and Power (CHP) facility, where a gasifier is coupled to two gas engines to produce electric power and heat [19]. As gasification technology, a steam blown fluidised bed gasifier is used. A slip stream from the plant has been used as feed stream for a Bio-SNG (Synthetic Natural Gas) pilot (1MW capacity), two FT diesel pilots (5kg/day and 1 barrel per day (bpd) respectively), a pilot for production of higher alcohols (0,001-0,002 cubic metres/day) and a pilot for hydrogen production (3 Nm^3/day).

The Güssing concept has been duplicated in several places for CHP applications by Repotec, Ortner Anlagenbau and also lately by GREG. The technology has been also scaled up about 4 times and implemented in Gothenburg, Sweden. The plant and the associated R&D activities were closed, as the operation was no longer economically viable with the end of the Feed-in-Tariff Power Purchase Agreement (PPA), in 2016.

Denmark

The Holsted Biogas plant is a Danish biomethane production plant, operating via anaerobic digestion, opened by NGF Nature Energy in August 2015. The plant processes around 400 thousand tonnes of waste per year, split roughly between 75% agricultural waste, mainly manure and deep litter, and 25% industrial waste. The biogas produced is cleaned, upgraded to natural gas quality equivalent and injected into the grid. Production of bio-methane at the plant is 1,800Nm^3/h of pure methane. The Joensuu bio-oil plant's has an annual production of 50,000 tonnes.

Germany

VERBIO's plant in Schwedt is a commercial bio-methane facility which operates on a mono-fermentation process, based on 100% straw as raw material. The biogas is purified and conditioned to natural gas quality and fed into the natural gas grid. This bio-methane is sold as bio-component into the CNG fuel market. All main types of straw have been tested and approved to be suitable for the plant: wheat straw, barley straw, rye straw, corn straw, rape straw and triticale straw. Straw logistics is also operated and optimized by VERBIO. In accordance with the German standards for the natural gas grid the biogas produced is upgraded in an amine scrubber. Subsequently, the bio-methane is compressed and fed into the gas grid. Fermentation residues are brought back to the fields as a high-quality bio-fertilizer. The capacity of the plant is going to be increased to 40,000 tonnes per year. A second plant of 10MW is under construction at Pinnow.

Netherlands

SCW Systems owns a biomethane-via-gasification plant in Alkmaar. The plant is a Hydrothermal Gasification (HTG) system to convert wet biomass to bio-methane. A demonstration unit of several modules up to 2MW output was built ructed in 2017. There are plans for scaling the demo plant up to 2. There are also other projects in planning, such as Ambigo (a 3MW bio-methane via gasification plant to be constructed in Alkmaar, Netherlands) and Bio2G (a 200MW bio-methane via gasification plant, in southern Sweden).

Sweden

In Sweden, the GoBiGas plant, owned by the city of Gothenburg and developed by Göteborg Energi (Gothenburg Energy), uses gasification on an industrial scale to convert biomass into advanced biofuel. It has been the first plant to inject biomethane into the national grid, and the first in the world for high quality biomethane from biomass through gasification [10]. The plant was built as a demonstration, but aimed of being commercially and economically viable when run in combination with a plant five times larger, once the demonstration phase ended [20].

The gasification technology implemented in the GoBiGas plant is a four-times scale up from the reference plant in Güssing, in Austria, and includes tar removal via RME scrubbing. Then there is a syngas upgrading phase and conversion sections. Active carbon filters are used for the removal of vapour phase tar species, the gas is compressed to 1.6MPa before the main treatment and synthesis section. Following this treatment, sulphur is removed in an amine wash and the H2/CO ratio is adjusted in a water gas shift reactor. Following the Water Gas Shift (WGS) reactor, CO_2 is removed in a second amine wash and the gas passes several methanation reactors using combinations of gas recirculation and gas cooling with heat recovery to control the temperature. Finally, the gas is dried to the grid dew point level by mol sieves before being to the grid interface, where it is compressed to the grid pressure. The plant commissioning started in late 2013 and, about one year later, the first Bio-SNG (Synthetic Natural Gas) was delivered to the grid. In 2018 the company decided to stop the operation due to technical and economic problems. Another Swedish biomethane plant is Lidköping Biogas - Air Liquide and Swedish Biogas International, and produces biomethane via anaerobic digestion.

The commercial plant, located in Lidköping, produces liquefied biomethane with a capacity of 12 tonnes/d. The biogas production process is based on local vegetable waste products from grain trade and food production. The substrates are macerated, mixed and heated to 38°C before being pumped into the digestion chamber. New substrate material is continually pumped into the process that produces biogas and bio fertilizer. The bio-fertilizer is pumped to a covered storage pool. Plant production is designed at 7.5MWth with an annual target of 60GWhth. Swedish Biogas International AB designed the production plant. The biogas is upgraded in accordance with the Swedish standard for biogas as a vehicle fuel in a water scrubber. A majority of the biogas is liquefied in the condensation plant. In order to liquefy the biogas, the majority of remaining CO2 (down to <10ppm) is purged by Pressure Swing Absorption (PSA) system before the gas temperature is lowered using the Brayton cycle. The technology allows for liquefaction in the span of 140 C (at 0.5MPa) to 161 C (at atmospheric pressure), depending on the developing requirements of the vehicle market. The liquefied biogas is stored in a 115m3, 20m tall insulated canister. The distributer, Fordonsgas Sverige AB (FGS), fills insulated 50m3 trailers every second day and transports the gas to filling stations in Gothenburg. A smaller portion (around 30%) of the biogas produced and upgraded to biomethane is delivered directly to FGS's two compressors, which fills mobile storage containers in one of six filling places.

UK

An example of UK biomethane production facility is the Bi-methane plant of Biogest Biogas/Greener for Life Ltd in Somerset, which produces biomethane via anaerobic digestion.

The plant produces at least 4,000 MWh electricity and 7.2 million m^3 of biogas/4.3 million m^3 of biomethane (40GWh) yearly using optimized feedstock mix of cattle slurry and manure, sugar beet, grass silage and maize silage. Feedstock deliveries to the Anaerobic Digestion (AD) plant with upgrade system enables the farmer to sustainably utilize the farm wastes while allowing the farmer to manage the manure and crop rotations more efficiently.

The plant is a 2-stage AD plant which is suitable for operation with almost all types of feedstock. Power output ranges from 250kW-2,000kW and a bio-methane production of 80Nm³/h-500Nm³/h. The design is based on an external main digester and an internal post-digester. The main digester is a ring canal, thereby allowing a controlled plug flow. Another UK biomethane plant is “Gogreengas” Pilot Plant, Swindon, which uses gasification as key technology. The plant is a development facility aimed at producing bio-SNG from refuse derived fuel (RDF) and biomass feedstocks. The project is a partnership between Cadent (aka National Grid Gas Distribution), Advanced Plasma Power (APP), Progressive Energy and Carbotech (a subsidiary of Viessmann).

Dried RDF and other feedstocks are converted to syngas in a two-stage gasification process using APP’s Gasplasma technology, i.e. fluidized bed gasifier at atmospheric pressure designed by Outokompou Energy, close-coupled with a plasma converter. The plasma stage removes tars leaving a syngas which is predominantly CO and H2. After further conventional gas processing, the syngas undergoes a WGS to adjust the proportions of the CO and H2, followed by catalytic methanation. The arising CO2 is removed from the methane using a pressure swing absorption unit to produce pipeline / vehicle quality Bio-SNG. The start-up year of the pilot plant was 2016, with a feedstock capacity of 0.4 tonnes/d. The project has prompted the construction of a commercial facility that aims to generate 22GWh/annum of grid-quality natural gas from waste wood- and refuse-derived fuel [21].

8.4 Bio-methanol production facilities

Advanced biomethanol production is getting of interest of the waste treatment sector as a solution to extract a valuable product from dishomogeneous waste materials like mixed urban waste. At present, industrial bio-methanol production facilities are available at demo-scale in few EU countries. The existing plants are listed below.

Netherlands

In the Netherlands, BioMCN has two plants, i.e. BioMCN commercial (operational) in Farmsum and another one (on hold) in Delfzijl, Groningen. The first one has a production capacity of 65000 t/y, while the second one 413,000 t/y, uses lignocellulosics as feedstock processed by means of gasification technology. Additionally, GIDARA Energy B.V. owns one plant in Amsterdam, with a production capacity of 875000 t/y uses organic residues and waste streams as feedstocks and the gasification technology. Moreover, a waste to bio-methanol plant in Rotterdam is planned to be built by a consortium composed by the companies *Enerkem*, *Shell*, *Air Liquide*, *Nouryon* and the Port of Rotterdam. The facility will convert 0,36 MMT of waste into 0,27 million cubic metres of biomethanol. *Enerkem* has plans to realize a similar project in Spain.

Spain
Enerkem, SA (Agbar) and Repsol own a 265,000 t/y plant in El Morell, which uses organic residues and waste streams as feedstocks and the gasification technology.

Sweden

The company Rottneros planned two plants (140,000 t/y) in Vallvik, onw using gasification and one fast pyrolysis of forest residues. The projects got cancelled. Södra owns an operational plant in Monsteras (5,250 t/y) which uses forest residues to produce methanol. Additionally, LTU Green Fuels is currently building a 4 t/d plant in Pitea, which uses the gasification technology. Finally, VaermlandsMetanol AB planned a plant in Hagfors, with a production capacity of 130,000 m3/y and which uses lignocellulosics as feedstock and the gasification technology.

8.5 FT-Liquids production plants

Austria
In Austria there is one plant (on hold) in Guessing, owned by Vienna University of Technology / BIOENERGY 2020+, whose production capacity is 5 kg/d. The technology adopted is gasification and the feedstocks used are lignocellulosics.

Finland
Sunshine Kaidi planned a project of FT-liquids plant (200,000 t/y) in Kemi, which was cancelled, using forest residues as feedstock and gasification.

France
In France there are two operational plants working in Dunkerque, both using lignocellulosics as feedstock and gasification as main technology. One plant is owned by the BioTfueL-consortium (60 t/y), and one by Total (8,000 t/y).

Germany
In Germany there are several plants.

CHOREN planned two plants but the projects were cancelled before 2012.

Additionally, there is an idle plant in Freiberg, namely Synthesis CHOREN alpha plant Freiberg, with a capacity of 53 t/y, using lignocellulosics as feedstocks. The technology is gasification.

There are two operational plants, one in Dresden (owned by Sunfire GmbH, with a production capacity of 58 m3/y), and one in Clausthal-Zellerfeld (owned by Synthesis Cutec Clausthal-Zellerfeld, with a production capacity of 0.02 t/y).

Finally, the Darmstadt University is planning a plant in Darmstadt, which uses Gasification and FT synthesis to process lignocellulosics.

Norway
Nordic Electrofuel AS planned the operation of a plant in Porsgrunn, with a production capacity of 8,000 t/y, which processes waste gases.

Turkey
TUBITAK owns an operational plant in Gebze, whose capacity is 250 t/y, and which employes gasification of forest residues.

UK
In UK there is a planned facility in the Ellesmere Port, owned by Fulcrum BioEnergy. The production capacity is 70,000 t/y, the technology adopted is gasification and the feedstocks to be processed are organic residues and waste streams.

9 Conclusion

On average, the EU produces annually around 190 TWh renewable diesel, 33.8 TWh of bioethanol, and about 26TWh of biomethane (of which only around 3.9 TWh of used as transport fuel). The renewable diesel is still largely produced by rapeseed, even if a strong contribution is given by the consumption of Used cooking Oil (UCO), and animal fats, considered advanced biofuels by the RED II. Among the technologies currently adopted for advanced renewable diesel production, Hydrogenation of Vegetable Oil is by far the most promising solution. At present, HVO (hydrogenated Vegetable Oil), also known as green diesel, is mainly obtained from HVO, and Palm Oil. At present, no more than 4 million cubic metres (20% of total renewable diesel production) is represented by HVO, and none of the feedstock used for HVO production are part of Annex IX, Part A, those which are mostly supported by the EU commission. Despite the low contribution, it is general consensus that HVO has promising perspectives, in particular related to that produced from low-ILUC feedstock obtained from oil crops cultivation in degraded and abandoned land, or in cover cropping with food and feed. Technology maturity and economic sustainability has been proven and policy support could play a key role for the market development of such advanced biofuel.

Bioethanol production, currently around 5 million cubic metres, is almost fully based on first generation feedstocks: sugar, sugar beet, corn. Lignocellulosic ethanol production doesn't overcome the 100,000 litres per year and it is mainly related to the activity of demonstrative plants. Alternative technologies do not contribute to the sector. Lignocellulosic ethanol represents the sole Low-ILUC alternative for bioethanol at commercial scale. For this reason the future development and growth of lignocellulosic ethanol market is crucial for the sustainable transition of bioethanol sector in Europe, and the support measures and the target established by the RED II could bring to a market take off in the next years.

Advanced biomethane, thus produced from organic waste and sludge, as well as animal manure and non-feed cover crops, has strong growth potentials. At present, 26TWh of biomethane are produced in EU, but most of it is used as energy source, not for transport. However, the EBA projections to have around 116 TWh of biomethane for transport in 2030 could make this biofuel crucial for decarbonizing the EU transport sector. The advantage of biomethane as transport fuel is that the technology is fully mature and well known everywhere. The barrier is currently represented by the infrastructure for the transportation, supply and certification of the biomethane as gaseous, Low-ILUC biofuels for transport. Another aspect to consider for the future projection of EU biofuel market is the growth rate shown by the most common biofuels investigated in this report. According to the above-reported data, bioethanol production volumes from 2011 to 2019 increased of 1,5 million cubic metres, with a total increase of about 35% compared to the 2011 production. Renewable diesel passed from around 12 to 16 million cubic metres, registering a growth of about 33% compared to figures of 2011. Figures are different, and much greater for biomethane. The biomethane production from 2011 amounted to about 750 GWh, and to around 2100 GWh in 2012, compared to the 26000 GWh of 2021, for an impressive market growth of about 3300% compared to 2011 and of 1000% compared on 2012. It is also true that biomethane market in 2011 and 2012 was at an early stage compared to bioethanol and renewable diesel sectors. In addition, the biomethane market growth has been supported by a set of strong national incentives, still in place in many EU member states, to the biomethane production plants from waste and residual materials. To date, the updated RED II and the support measures to advanced biofuels sector proposed by the European Commission could be the starting point for a new growing market trend for all of the biofuels types investigated in this report, with promising perspectives to reduce the overall environmental footprint of transport sector in Europe within 2030.

Annex 1: List of EU biorefineries

Name of Production Plant	Country
Hallein Mill	Austria
Heiligenkreuz Pulp Mill	Austria
Lenzing Pulp Mill	Austria
Pischelsdorf Biorefinery	Austria
Aalst Plant	Belgium
Alco Bio Fuel Plant	Belgium
Avantium	Belgium
Bioro	Belgium
BioWanze S.A. (CropEnergies)	Belgium
Galactic Escanaffles	Belgium
Oleon NV 1	Belgium
Oleon NV 2	Belgium
Proviron	Belgium
Almagest AD	Bulgaria
Essentica Ethanol Factory	Bulgaria
Chrudim Plant (Tereos)	Czech Republik
Dobrovice Plant (Tereos)	Czech Republik
Paskov Mill	Czech Republik
Daka ecoMotion	Denmark
EMMELEV A/S	Denmark
Inbicon Biomass Refinery	Denmark
Altia Koskenkorva	Finland
Cellunolix Ethanol Plant (NEOT)	Finland
Enocell Mill	Finland
Forchem Biorefinery	Finland
Hämeenlinna Biolonix Plant (St1 Biofuels Oy)	Finland
Joensuu Bio-oil Plant	Finland
Kraton Refinery	Finland
Lahti Etanolix Plant (St1 Biofuels Oy)	Finland

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Lappeenranta Etanolix Plant	Finland
Metsä Bioproduct Mill	Finland
Närpiö Etanolix Plant	Finland
Neste Biorefinery in Kilpilahti Refinery	Finland
Pulp Mill 1	Finland
Pulp Mill 2	Finland
Pulp Mill 3	Finland
Sunila Mill	Finland
UPM Lappeenranta Biorefinery	Finland
Abengoa Biorefiniery Lacq Plant	France
Artenay Plant (Tereos)	France
Avril (Diester Industrie) 1	France
Avril (Diester Industrie) 2	France
Avril (Diester Industrie) 3	France
Avril (Diester Industrie) 4	France
Avril (Diester Industrie) 5	France
BASF Health and Care Products France S.A.S. 1	France
BASF Health and Care Products France S.A.S. 2	France
Bio-based Succinic Acid Plant	France
Bucy Plant (Tereos)	France
Connantre-Morains Plant	France
D.R.T. Derivatives Résiniques and Terpeniques	France
Distillery Arcis sur Aube (Cristal Union)	France
Distillery Bazancourt II (Cristal Union)	France
Distillery Cristanol (Bazancourt I) (Cristal Union)	France
Distillery Toury (Cristal Union)	France
Gattefossé Holding	France
Kraton Refinery	France
Lestrem Starch Biorefinery	France
Lillebone Plant	France
Lillers Plant	France

Nesle Plant	France
Oleon S.A.S.	France
Origny Plant	France
Roquette-Bioethanol-Beinheim	France
Ryssen Alcools S.A.S., Loon-Plage (CropEnergies)	France
Saint Louis Sucre Eppeville	France
Soufflet (SMBE)	France
Stearinerie Dubois Fils	France
Tembec Tartas	France
TOTAL La Mède Biorefinery	France
ADM Hamburg AG -Hamburg Plant-	Germany
ADM Hamburg AG -Leer Plant-	Germany
ADM Mainz GmbH	Germany
Baerlocher GmbH	Germany
Barby Plant (Cargill)	Germany
BASF Personal Care and Nutrition GmbH 1	Germany
BASF Personal Care and Nutrition GmbH 2	Germany
BIO.Diesel Wittenberge GmbH	Germany
Bioeton Kyritz GmbH	Germany
Biopetrol Rostock GmbH	Germany
Biowerk Sohland GmbH	Germany
Biowert Biorefinery	Germany
BKK Biodiesel GmbH	Germany
Bunge Deutschland GmbH	Germany
Cargill GmbH	Germany
Cremer Oleo GmbH & Co. KG	Germany
CropEnergies Bioethanol GmbH	Germany
EAI Thüringer Methylesterwerke GmbH (TME)	Germany
Ecogreen Oleochemicals GmbH	Germany
EcoMotion GmbH 1	Germany
EcoMotion GmbH 2	Germany

EcoMotion GmbH 3	Germany
Emery Oleochemicals GmbH	Germany
Evonik Industries AG	Germany
Ful 21 Klein Wanzleben Refinery (Nordzucker)	Germany
German biofuels GmbH	Germany
Glencore	Germany
Gulf Biodiesel Halle GmbH	Germany
IOI Oleo GmbH 1	Germany
IOI Oleo GmbH 2	Germany
Kao Chemicals GmbH	Germany
KFS Biodiesel GmbH & Co. KG 1	Germany
KFS Biodiesel GmbH & Co. KG 2	Germany
KFS Biodiesel GmbH & Co. KG 3	Germany
KL Biodiesel GmbH & Co. KG	Germany
KLK Emmerich	Germany
Kraton Refinery	Germany
KWST GmbH	Germany
Louis Dreyfus Commodities Wittenberg GmbH	Germany
MBF Mannheim Biofuel GmbH	Germany
NEW Natural Energy West GmbH	Germany
Nordische Oelwerke (Walter Carroux GmbH & Co KG)	Germany
Oleon GmbH	Germany
Osterländer Biodiesel GmbH & Co. KG	Germany
Peter Greven GmbH & Co. KG	Germany
Petrotec AG	Germany
PROKON Pflanzenöl GmbH Magdeburg	Germany
Renewable Energy Group Europe (REG)	Germany
Sasol Olefins & Surfactants GmbH	Germany
Süd-Chemie AG (Clariant)	Germany
Suiker Unie GmbH	Germany
TECOSOL GmbH	Germany

Ullrich Biodiesel GmbH/IFBI	Germany
Verbio Diesel Bitterfeld GmbH & Co. KG (MUW)	Germany
Verbio Diesel Schwedt GmbH & Co. KG (NUW)	Germany
Verbio Ethanol Schwedt GmbH & Co. KG	Germany
Verbio Ethanol Zörbig GmbH & Co. KG	Germany
Vesta Biofuels	Germany
Agrár-Béta Mezőgazdasági Kft.	Hungary
Hungrana Bioeconomy Company	Hungary
Kall Ingredients Kfr	Hungary
Pannonia Ethanol	Hungary
Rossi Biofuel	Hungary
Carbery	Ireland
Ambrogio Pagani SpA	Italy
BASF Italia S.r.l.	Italy
Caserta Levulinic Acid PLAnt	Italy
Cereal Docks SpA	Italy
Dp Lubrificanti S.r.l.	Italy
Eco Fox S.r.l.	Italy
Ecoil	Italy
Eigenmann & Veronelli SpA	Italy
Eni	Italy
FACI SpA	Italy
Green Oleo S.r.l.	Italy
Ital Bi Oil S.r.l.	Italy
Ital Green Oil S.r.l.	Italy
Italmatch Chemicals SpA	Italy
Llsap Biopro	Italy
Masol Continental Biofuel S.r.l.	Italy
Mater Biopolymer	Italy
Matrìca	Italy
Novamont MaterBi	Italy

Novamont Orego-Bi	Italy
Novaol S.r.l.	Italy
Oil.B S.r.l.	Italy
Oxem SpA	Italy
Pfp Italia S.r.l.	Italy
SO.G.I.S. Industria Chimica SpA	Italy
Spiga Nord SpA	Italy
Temix Oleo S.r.l.	Italy
Cassano Succinic Acid Plant	Italy
Crescentino Bioethanol Plant	Italy
Mater-Biotech	Italy
Saluzzo Plant (Tereos)	Italy
Biopetrol Industries AG	Netherland
Abengoa Bioenergy Europoort Plant	Netherlands
Glencore	Netherlands
Greenmills Amsterdam	Netherlands
Musim Mas Europe	Netherlands
Peter Greven Nederland	Netherlands
Rotterdam Neste Biorefinery	Netherlands
Sas van Gent Plant (Cargill/Royal Nedalco)	Netherlands
Shell Chemicals Europe B.V.	Netherlands
Suiker Unie Vierverlaten	Netherlands
Wilmar Trading Europe B.V.	Netherlands
Borregaard Sarpsborg	Norway
Chelmza Alcohol Production Plant	Poland
Goswinowice Ethanol Plant (Bioagra S.A).	Poland
Orlen	Poland
Caima Mill	Portugal
Beta Renewables / Energochemica	Slovakia
ENVIRAL	Slovakia
Abengoa Teixeiro Plant	Spain

Abengoa Valle de Escombreras Plant	Spain
BASF Espanola S.L.	Spain
BASF/Purac	Spain
Bio Oils	Spain
Biocom Energía	Spain
Hebron S.A.	Spain
Infinita Musim Mas	Spain
Kao Corporation S.A. - Olesa Factory	Spain
Kao Corporation S.A. Mollet del Vallés	Spain
Saras	Spain
Sniace Torrrelavega	Spain
UNDESA (Unión Deriván, S.A.)	Spain
Abengoa Babilafuente Ethanol Plant	Spain
AAK Sweden AB	Sweden
Domsjö Pulp Mill	Sweden
Gothenburg Ethanol (Etanolix) Plant (NEOT)	Sweden
Kraton Refinery	Sweden
Lantmännen Agroetanol A.B.	Sweden
Örnsköldsvik SEKAB Biorefinery	Sweden
Perstorp	Sweden
Pulp Mill	Sweden
SEKAB ETECH	Sweden
Södra	Sweden
Södra Cell Mönsterås	Sweden
Södra Cell Mörrum	Sweden
SunPine	Sweden
Procter & Gamble	Switzerland
BASF Tuerk Kimya Sanayi ve Ticaret Ltd. Sti.	Turkey
May Group	Turkey
Argent Energy	UK
Celtic Renewables	UK

CRODA Europe Ltd	UK
Ensus Ltd. - Wilton (CropEnergies)	UK
Ensus UK Limited	UK
Esterchem Limited	UK
Grimsby Pulp Mill	UK
Manchester Biorefinery (Cargill/Royal Nedalco)	UK
Selby Plant (Tereos)	UK
Vivergo Fuels	UK
Wissington Factory (Bristish Sugar)	UK

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