Bioenergy Retrofits for Europe's Industry

EU Horizon 2020 no. 8178999
01/10/2018-31/09/2021
www.biofit-h2020.eu

# Summary Paper for policy makers: retrofitting Europe's industry with bioenergy

November 2019

WIP RENEWABLE ENERGIES

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| *Publisher:* | **WIP Renewable Energies, Sylvensteinstrasse 2, 81369 Munich, Germany** | |
| *Deliverable no.* | **D2.6** | |
| *Nature, dissemination level* | **Report, Public** | |
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| *Date, version* | **November 2019** | |

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# 1 Introduction

The BIOFIT project, supported by the Horizon 2020 programme of the European Union, aims to facilitate the introduction of bioenergy retrofitting in Europe's industry, thus reducing greenhouse gas emissions. Retrofitting means often lower capital costs, shorter lead times, faster implementation, less production time losses and lower risks. The project facilitates the introduction of bioenergy retrofitting in five specific industries, namely:

- First generation biofuels industry
- Pulp and paper industry
- Fossil refineries
- Fossil power generation
- Combined Heat and Power (CHP)

The selection of these industries is due to the specifications of the call text in the Horizon 2020 programme, under which BIOFIT was submitted in the call for proposals. In the present report, the fossil power generation sector and the Combined Heat and Power (CHP) sector are described in one combined chapter, as many aspects are relevant for both sectors.

Actions on retrofitting the energy industry are closely linked to the legal, institutional, and political frameworks at national and European level. This is also shown by the large discrepancies of the energy sectors in the different countries in Europe or overseas.

The present "Summary Paper for policy makers: retrofitting Europe's industry with bioenergy" provides an overview on the challenges, barriers and technical solutions for the addressed sectors and gives recommendations for the policy makers. It presents the current ongoing discussions within the project consortium and with stakeholders, which is a snapshot after one year of project implementation. It also summarizes the results of a project workshop on 25 September 2019 in Thessaloniki, Greece, at which project partners and external stakeholders participated. The content of this summary paper will be taken up to formulate more extended recommendations at the end of the BioFit project.

# 2 First generation biofuels industry

## 2.1 Market overview of the sector

The 1st generation biofuels sector in Europe involves the production of biodiesel (fatty acid methyl esters - FAME), hydrogenated vegetable oil (HVO) and bioethanol from various food crops. FAME and HVO are mostly produced from oil bearing crops such as rapeseed. Bioethanol is produced from sugar or starch containing crops, such as sugar beet, grain and wheat. The main advantage of these fuels is that they can be blended with regular transport fuels. Furthermore, biogas can efficiently be upgraded to biomethane, which is compatible with the compressed natural gas (CNG) infrastructure. An overview on the market shares of the different biofuels is shown in Figure 1. The amount of 2nd generation biofuels is currently negligible.

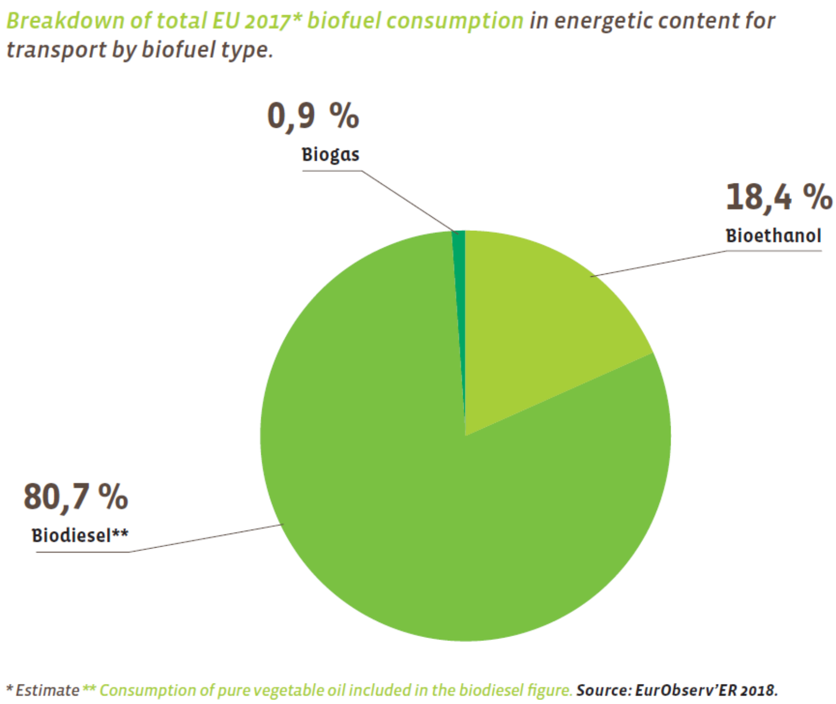


**Figure 1: Breakdown of total EU 2017* biofuel consumption in energetic content for transport by biofuel type (Source: EurObserv'ER 2018b)**

For Europe, biodiesel production is more important than bioethanol production with a production of 11.5 million t/year of biodiesel in 2015, against 1.9 million $m^3$/year for bioethanol. These quantities are produced by numerous dedicated plants scattered across Europe. Recently, production volumes of biofuels have been stable or sometimes even decreasing, because of decreased support from governments (e.g. Spain has decreased blending requirements) (Figure 2), although comprehensive certification systems are being used to assess and guarantee the sustainability of 1st generation biofuels. For the future extension of biofuel production the 1st generation biofuels are to be supplemented by 2nd generation biofuels. The latter involve not food crops but lignocellulosic feedstocks and waste oils, have a better GHG balance, and are therefore not subject to the cap on biofuels from food and feed crops to be imposed by the revised Renewable Energy Directive (RED II).

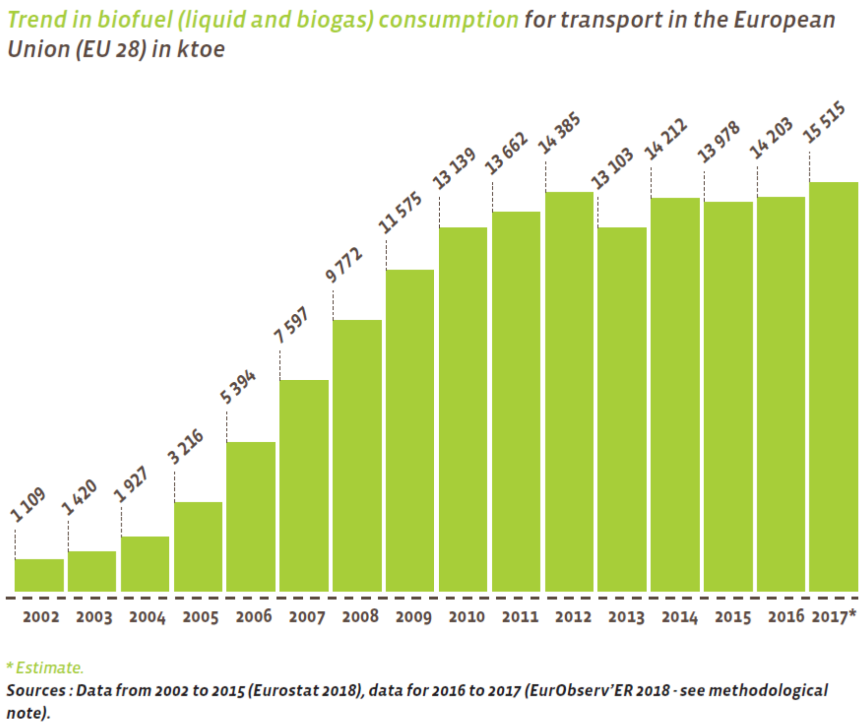


**Figure 2: Trend in biofuel (liquid and biogas) consumption for transport in the European Union (EU 28) in ktoe (Source: EurObserv'ER 2018b)**

## 2.2 Technical solutions for biomass integration

Opportunities for retrofitting are the conversion or extension of 1st generation biofuels plants to produce more – or only – 2nd generation biofuels, by (e.g.) cellulosic ethanol add-ons, multi-feedstock biodiesel add-ons or biogas add-ons. Other retrofit options include improving the GHG balance (e.g. by producing biogas from waste streams, using biomethanol for biodiesel production) or more advanced electrofuel enhancements.

Many vegetable oil-based biodiesel plants suffer from critical economics. Some biodiesel plants were not well designed and/or operated (by small companies without sufficient expertise in engineering and plant operations). A common approach to retrofitting of these plants is to allow the use of cheaper waste oils and fatty acids, which can improve economics and leads to better plant utilization. This requires the installation of dedicated pretreatment equipment to adapt to the waste oils. It is an option especially for smaller biodiesel plants. Best practise examples are the Elin Verd biodiesel plant in Volos, Greece or the Crimson Biodiesel retrofit in Bakersfield, California, commissioned by BDI from Austria.

Furthermore, the retrofitting of the purification section for the biodiesel can be conducted to produce biodiesel of a better quality. This opens additional markets with special requirements, like suitability for low temperatures in Scandinavia. Also a better utilization and valorization of by-product (fatty-acids, glycerol and soap stock) can be achieved by retrofitting biodiesel plants.

For the bioethanol plants, retrofitting could consist of measures like biogas production from vinasse or stillage, the leftovers of the alcohol production. The remaining organic compounds in the vinasse or stillage are anaerobically fermented to biogas which is rich in methane content and which can be used as an alternative to natural gas. This technology has been successfully installed at some bioethanol plants (e.g. the Suiker Unie bioethanol plant in Anklam, Germany or the bioethanol plants of Verbio).

Furthermore, existing bioethanol plants could be retrofitted to be able to process lignocellulosic feedstocks like straw and produce advanced biofuels according to the definition in RED II. This could be done by either installing additional production capacities dedicated to lignocellulosic feedstocks or repurposing the existing plant. Also, the possibility to extend the bioethanol process by a so-called alcohol to jet (ATJ) process is assessed within the BIOFIT project. Synergies between the two processes might help to improve the economy of the production of ATJ-biokerosene for the aviation sector.

### 2.3 Policy recommendations

When comparing the goals for emission reductions in the transport sector with the development of sustainable alternatives, it becomes clear that much production capacity has to be build up. While doing this, retrofitting could mainly make sense when additional fuel is produced or when the efficiency of the processes can be increased. Changing from one biobased feedstock (1G) to another biobased feedstock (2G) may lead to the production of a biofuel that is considered more sustainable, but which does not contribute significantly to the reduction of fossil fuels in the transport sector. However, stirring away from food-crop based (1G) biofuels towards advanced non-food (2G) biofuels is still important in keeping up with changes in regulatory framework and meeting the targets set for the bio-content on transport fuels.

In general, the European biofuel installations are fairly new, since most of them have been built after 2005. Therefore, costly investments in retrofitting measures in the existing infrastructure may seem early from a plant operator's view. Policy recommendations for the biofuel sector are thus:

- To increase the contribution of biofuels to the climate goals, biofuels need to be as sustainable as possible and substitute as much fossil fuels as possible. Biofuel policy should **promote advanced biofuels in addition to the current biofuel production**. This would encourage investments in retrofits and new plants. Redefinition of (parts of) existing biofuels to be advanced biofuels should be avoided, since they do not contribute to the goal of additional substitution of fossil fuels.
- If the definition of Annex IX waste streams of the RED II is not uniform for all Member States. This creates individual markets per country and leads to confusion due to

different waste definitions and support systems. , a submarket or increased competition among the countries is going to be created. Investments in new plants for second generation biofuels are currently not attractive. Therefore, the definition of the waste materials should be clarified and identical for all Member States.

- The lack of penalties for not-compliance with the REDII goals is an obstacle for the investment into second generation biofuels. If penalties become a part of the "business plan" investments in advanced biofuels, new plants might become feasible. For this, a long-term secured regulation without loopholes is important.

- The same minimum penalties for not reaching the REDII mandates in time should be imposed on all Member States. Furthermore, they must be high enough in order to be effective.

- Consumers currently do not have the possibility to choose between fossil and renewable fuels at the gas station. At best, pure renewable fuels (E85, B100) should be available at the stations. In countries like France and Sweden, it is shown that pure biofuels can be brought to the market successfully. At least the benefits of renewable fuels - or their shares in blends with fossil fuels - should be promoted and visible to the customer. It should also be obligatory for car manufacturers to provide warranties for the use of higher blends (E15, B20) with their cars.

- Since few flex fuel cars are sold on the European market, some customers choose to add small conversion kits to their cars. These technologies for flex fuel cars are available and allow consumers to choose between all different blends of gasoline and pure biofuels (E85, B100). However, this typically leads to a loss of warranty for the car. Car manufacturers should therefore have to maintain the warranty for the car when the consumers decide to include this technology.

- Biomethane is an available advanced biofuel to substitute or to be blended with natural gas, but lacks possibilities to be used in the transport sector. The buildup of infrastructure like fueling stations for compressed natural gas should be supported. Furthermore, biomethane injection into the natural gas grid must be simplified and related barriers removed.

- Some of the valuable waste streams for the production of biofuels are scattered and difficult to mobilize. To improve the availability of waste streams for biofuel production, residues and waste collection systems should be improved and encouraged. For example, for the collection of UCO, there should be a certification/control system to avoid fraud. With animal fat such a stringent system, based on the EU hygienic regulation, exists.

- The biofuels sector is heavily influenced by regulations. These regulations also have a large influence on the economy of investments in retrofitting. Changes in the regulations should thus be made with caution in order to keep up the plant operator's trust in their business plans. The risk of change of regulations seems to be considered very high, which apparently hinders investments in the biofuel sector.

# 3 Pulp and paper industry

## 3.1 Market overview of the sector

The pulp and paper industry includes companies that use wood as raw material to produce pulp, paper, paperboard and other cellulose-based products. Pulp is a very important raw material. It is a lignocellulosic fibrous material which is prepared by chemically or mechanically separating cellulose fibres from wood, fibre crops, waste paper, or rags. The pulp is fed to a paper or cardboard machine where it is formed, and the water is removed from it by pressing and drying processes.

According to the Confederation of the European Paper Industries (CEPI, 2019), the paper and board production in the CEPI member countries[1] was stable with 92.2 million tonnes in 2018, compared to the previous year, according to preliminary figures. The market is characterized by new capacities, but also closures.

The Pulp and Paper industry sector is already using 685 PJ biomass (about 60%) of their total fuel consumption, which was more than 1,165 PJ in 2016[2]. The primary energy use was 1,328 PJ in 2016. There are roughly 150 pulp mills and 750 paper mills in Europe.

The industry has undergone some consolidation, while at the same time there is ample interest in high-valued bio-based products such as biofuels, bio-composites and bio-based plastics. Because many pulp mills no longer are integrated to paper mills, their own energy consumption is decreasing, which opens-up the opportunities for production of higher-valued bioenergy products from their residues.

The different side streams from the pulp and paper industry include sludge, bark, and wood processing wastes. Their main renewable energy source is bioenergy generated using wood handling residues. In addition, per 1 ton of paper produced[3], about 50 kg of dry sludge is formed. Sludge from the pulp and paper industry is the organic residue after wastewater treatment in a pulp and paper mill. It is a combination of three different categories: primary sludge, secondary sludge and deinking sludge[4].

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[1] Austria, Belgium, Czech Republic, Finland, France, Germany, Hungary, Italy, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom

[2] Statistical data source: http://www.cepi.org/keystatistics2017

[3] See https://link.springer.com/book/10.1007%2F978-3-319-11788-1

[4] https://www.sciencedirect.com/science/article/pii/S0960852416304874?via%3Dihub

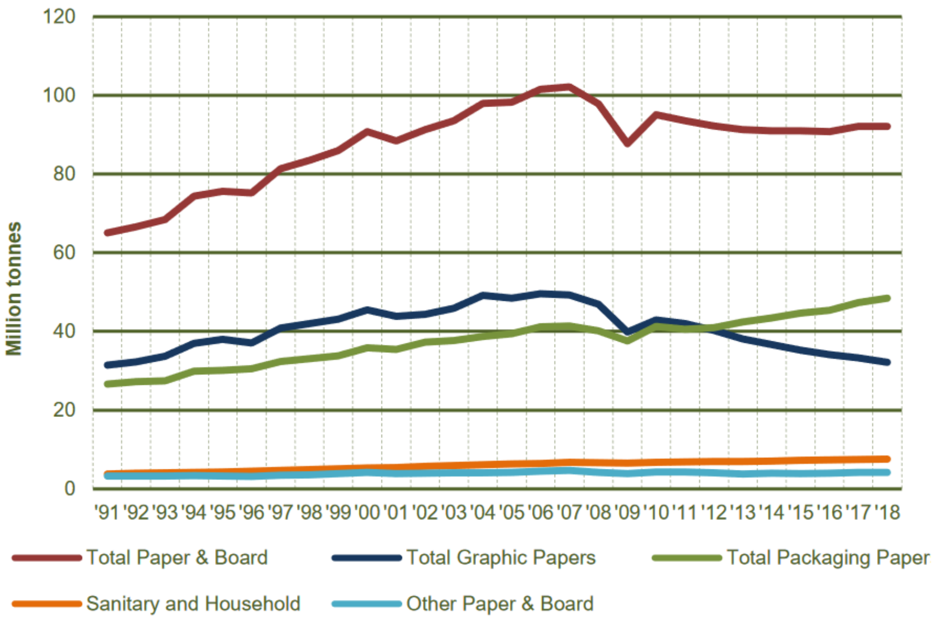


**Figure 3: Production of paper and board in CEPI countries (CEPI, 2019)**

## 3.2 Technical solutions for biomass integration

Bioenergy retrofitting in the pulp and paper industry can be used to replace fossil fuels with renewable alternatives on-site of the pulp and paper plants. It can also produce renewable fuels from process side streams for external markets. Both options are presented below.

***Replacing fossil fuels on-site***

In 2018, 34.2% of primary energy consumption in pulp and paper sector was based on fossil fuels (CEPI, 2019). Especially paper mills utilizing recycled paper raw material are today often using fossil fuels (such as natural gas, coal, and fuel oil) in their energy production. These mills can have difficulties in accessing the biomass feedstock profitably and/or sustainably. If the biomass feedstock supply can be guaranteed, the combustion processes of these mills can be retrofitted to bioenergy either fully or partially. The possible fuel conversions include utilizing biomethane instead of natural gas, gasified biomass instead of natural gas, solid biomass fuels instead of coal, and bio-oils instead of fuel oil. In addition, utilizing the wastewater treatment sludge to produce biogas or biocoal can increase the bioenergy share and energy self-sufficiency of these paper mills.

Pulp mills and integrated mills are utilizing biomass feedstock effectively on-site for energy production already today. In the pulping industry, bark (residue from debarking) and biogas (from anaerobic digestion of sludge from mill's wastewater treatment) are used commonly instead of fossil fuels. In all pulping processes, bark which is a side product not used in the pulp production, can be used to produce heat and power in a separate boiler or can be gasified into fuel gas. The fuel gas can be burned instead of fossil fuel in the lime production in the chemical recovery. In addition, it can be sold or refined into liquid or gaseous fuels. In sulphite pulping, the sugars remaining in the black/brown liquor can be converted into biogas, whereas lignin, which is converted into lignosulphonates is typically sold and not combusted.

***Producing renewable fuels for external markets***

Besides replacing fossil fuels on-site, another option is to retrofit the facility to produce renewable fuels for external markets. In sulphite cooking process, valorisation of hemicellulose to bioethanol or biogas production is an option. In the Kraft process, valorisation of sugars after the cooking from black liquor is difficult, because they are degraded in the process. In Kraft process, lignin can be separated from black liquor and used in the limekiln as fuel directly or converted into biocrude by hydrothermal liquefaction. The biocrude can be further refined into high quality transportation biofuels in an oil refinery. It is also possible to convert part of black liquor directly into biocrude by hydrothermal liquefaction.

In the Kraft process, also other side streams are produced, such as methanol from black liquor evaporation and tall oil from soap separated in the evaporation of black liquor. Methanol can be cleaned from smelly impurities and used as biofuel or chemical. The tall oil or heavy fractions from further refining such as tall oil pitch can be further converted into renewable diesel and gasoline fuels. For semi-chemical processes, such as near neutral sulphite pulping, acetic acid containing condensates can be used typically in biogas production.

## 3.3 Policy recommendations

Companies in the pulp and paper industry are facing different kinds of situations in relation to their potential for bioenergy retrofits. There are companies which already use and produce high shares of bioenergy, and actively seek for new production possibilities and high-value end-products, which may include biofuels but also many other products. On the other hand, there are also companies that have limited access to biomass and that currently rely mostly on fossil energy sources. Common challenges for the whole industry are pressures related to cost-efficiency and concerns related to sustainability and availability of biomass for both raw material and energy production purposes, and the role of forests as carbon sinks. Some regulatory barriers for using pulp and paper production residues for energy purposes have been identified. These bottlenecks should be further reviewed, and the compatibility of the waste and energy regulation should be clarified, taking into account the options provided by new innovative technologies, in addition to the necessary demands related to health, safety and sustainability.

Preliminary policy recommendations for promoting bioenergy retrofits in the pulp and paper industry include the following:

- Options related to bioenergy retrofitting in pulp and paper industry are at different levels of technical maturity, which may hinder the possibilities for their exploitation. High CAPEX is often mentioned as a barrier for investments. For less mature technologies, it is difficult to estimate the CAPEX with high accuracy. Replacing fossil fuels can be both technically and economically viable, but financial support for the investment may be required.

- Many commercial processes for side streams utilisation already exist. These include technologies such as bark combustion, bark gasification, biogas production from sludge, ethanol production from black liquor in sulphite mills, tall oil conversion into transportation fuels and lignin separation from Kraft black liquor. Bark and black liquor conversion via gasification into biofuels, methanol purification, biocrude production from lignin and black liquor and hydrothermal carbonisation of mill sludge have been demonstrated in pilot units or demonstration plants connected to pulp mills. In order to facilitate the market uptake of emerging technologies for bioenergy retrofitting in pulping industry, R&D funding as well as investment support should be targeted to new technologies that allow efficient side-stream utilisation, increase overall energy-efficiency and are able to reduce greenhouse gas emissions.

- Paper mills that are not integrated with pulp mills can have difficulties in accessing the biomass feedstock profitably and sustainably, and are today using other fuels (such as natural gas, coal, and fuel oil) in energy production. Research and funding should be allocated for studying the possibilities for broadening their feedstock base and increasing awareness of related challenges. Potential means could include support for finding alternative feedstocks, investments in energy efficiency and other new technological solutions that could help in decarbonisation of the sector.

- The industry sector is exposed to international competition and, thus, the required solutions for decreasing fossil fuels in the sector should be cost-efficient[5], and possibilities for new funding mechanisms should be considered.

[5] CEPI. 2018. The challenge: decarbonising whilst being recycling pioneer – Summary for policy makers. Policy Briefing

# 4 Fossil refineries

## 4.1 Market overview of the sector

Fossil refineries are usually very large industrial complexes where crude oil is processed and refined into more useful products such as petroleum naphtha, gasoline, diesel fuel, asphalt base, heating oil, kerosene, and liquefied petroleum gas (LPG). The crude refining capacity of the around 90 operational refineries in the EU is 13.2 million barrels / day, representing 13% of world capacity. The transport sector in the EU is currently for 95% dependent on liquid (fossil) fuels and is responsible for more than 25% of GHG emissions in the EU.

It is – also within the sector itself - accepted that a **main challenge of the refining sector** is how to manage the transition to a low-carbon economy[6]. The European platform organisation of refineries, FuelsEurope, has issued its own vision document "Vision 2050"[7] in 2018, in which they lay out their vision for a low-carbon future for the refining industry. The main points of this vision are commitment to the global climate change challenge, increase use of new feedstocks such as renewables, waste and captured $CO_2$, need for technology development regarding sustainable biofuels, CCS/CCU, renewable hydrogen and power-to-liquids. From these main points, it is clear that the European refining sector wants to reduce its carbon emissions substantially, and that bioenergy and biofuels are seen as part of this solution.


**Figure 4: Refineries and steam crackers in EU-28 (2016) (Source:[8]: Petrochemicals Europe, 2019)**

[6] https://ec.europa.eu/energy/sites/ener/files/documents/Highlights%20%26%20summary%20of%20the%206th%20EU%20Refining%20Forum%20FINAL.pdf

[7] https://www.fuelseurope.eu/vision-2050/

[8] https://www.petrochemistry.eu/about-petrochemistry/petrochemicals-facts-and-figures/maps-refineries-and-crackers/

## 4.2 Technical solutions for biomass integration

Biomass integration in existing refineries has two very important advantages:

- The existing refinery infrastructure can be used, which means lower capital costs, quick ramp-up possibilities, and utilisation of existing expert knowledge on transportation fuels.
- Retrofitting existing refineries can mean avoidance of closure, thereby avoiding costly measures such as soil sanitation. Refineries have also a role in the regional economies, meaning that their continued operation has also an important socio-economic effect.

Near-future opportunities for biomass integration in refineries can be divided into the two main categories as described below.

***HVO biodiesel production in existing refineries.***

HVO stands for Hydrogenated Vegetable Oils. The main concept here is that renewable liquid oils, such as palm oil and used cooking oil, are upgraded to renewable transport fuels in refineries. This is done by hydrogenation. HVO biodiesel can be produced in existing refineries or in stand-alone installations.

HVO production is currently carried out on a large scale by ENI in Porto Marghera (Italy), Total (La Mede, France), PREEM (Gothenburg, Sweden), and Neste Oil (Porvoo, Finland)[9]. Total HVO production in the EU is 2.6 million tonne/year. Biomass feedstocks range from primarily palm oil (ENI) to Used Cooking Oil (UCO) (Total) and tall oil (PREEM).

Advantages of HVO biodiesel is that it has characteristics that are very similar to normal diesel, does not suffer from low temperature 'freezing' issues, it is – unlike regular biodiesel - not susceptible to the 'blend wall', which means that it can be used as an actual drop-in biofuel without limitations. It is therefore no surprise that HVO biodiesel production in Europe is set to rise to 4 million tonne/year in the next few years. Already 17% of the total biodiesel production in the EU is HVO biodiesel.

Main problem is the feedstock. Collecting large quantities of sustainable liquid biogenic oils in one location (a refinery) is a serious challenge.

***Upgrading of Intermediate Bioenergy Carriers from lignocellulosic biomass.***

Other options are to upgrade intermediate bioenergy carriers (IBCs) produced from lignocellulosic biomass like pyrolysis oil or bio-oil from hydrothermal liquefaction to transport

[9] https://www.neste.com/companies/products/renewable-fuels/neste-my-renewable-diesel

fuels. The last option has not been demonstrated on full scale to date, but use of pyrolysis oil in a refinery will be implemented full-scale in 2020 in Europe in the Lysekil refinery of PREEM[10].

Use of intermediate bioenergy carriers has advantages for refineries because it allows for the cost-effective transportation to a refinery of the large quantities of biomass that are required. This is because of the large 'energy density' and thus relatively low transport costs of IBCs. Furthermore, using an intermediate bioenergy carrier means a homogeneous feedstock, often in a (liquid) form which is suitable for co-feeding. Lastly, IBCs can be produced from lignocellulosic biomass which is available in far large quantities than typical HVO feedstocks.

## 4.3 Policy recommendations

The policy recommendations reflect mostly one key barrier: the availability of large amounts of biomass. Since refineries are large-scale enterprises, large quantities of sustainable biomass need to be available at one location to make transport fuels cost-effective.

**Policy recommendations on improving biomass feedstock mobilization**

Many actions can be undertaken to *improve the availability of biomass*. Concrete examples are:

- Regarding agricultural and forestry residues collection, networks can be facilitated by removing legislation that inhibit large scale collection and storage of biomass.
- The cultivation of energy crops on marginal lands should be stimulated i.a. via demonstration projects and legislation
- For Used Cooking Oils (UCO) and animal fats collection networks are not functioning optimally everywhere in Europe. A combination of stimulus (incentives for people to turn in their waste) plus good logistics can be beneficial. This should be set up and stimulated by governments. For animal fats, proper disposal practices should be better enforced and monitored. Fats from waste water treatment plant (trap grease) could also become a new source of waste fat streams for liquid biofuel production.

**Other policy recommendations**

- Intermediate bioenergy carriers can help in getting feedstock to the refineries. These technologies should be stimulated, not only when direct related to refinery feedstock supply, but also for other uses so that the required volumes of IBCs become available and IBCs can be traded like a commodity.
- There is a need for a Europe-wide definition for determining the sustainability of biofuels from co-feeding. Current work on a Europe-wide definition should be conducted with diligence, speed and in cooperation with the sector.

[10] https://www.preem.com/in-english/investors/corral/renewable-fuel-projects/

- To be able to freely sell/transfer 'green transport fuels' that contain also fossil fuels, a certification system should be developed and implemented.

- Legislation regarding blending of HVO is not always appropriate. It does not acknowledge the green benefit arising when HVO is blended with regular diesel. This decreases the market opportunities for green transport fuels, and thus the economic value. To address this, EU institutions will have to come up with a calculation formula to derive the "green content" of fuels produced through HVO co-processing. A similar procedure is already in place for gasoline, where provision is made for accounting bio-content of ethers produced using bio-MeOH (MTBE/TAME) or Bio-EtOH (ETBE/TAEE).

# 5 Power and combined heat and power generation

## 5.1 Market overview of the sector

Power plants without heat use as well as combined heat and power plants (CHP) that are operated with fossil fuels (natural gas, coal, fossil oil) are providing large shares of energy in many European countries. The size of the power plants is usually large-scale. The size of CHP facilities varies from very small units, being even household CHP units, to large scale facilities in the hundreds or thousands megawatt range.

About 25 % of power production in Europe is still coming from coal (Agora Energiewende and Sandbag, 2018) and more than 1,000 hard coal and lignite fired power plants remain operational in the EU, Switzerland, Norway and Turkey (Energy Brainpool, 2018). Coal firing is reliable and cost effective, but there is pressure to reduce carbon emissions and other pollutants emissions, with several countries (e.g. the Netherlands) pledging to phase out coal power production.

Compared to electricity from solar or wind, electricity from biomass has a lower share in the renewable energy production in Europe. A key advantage of biomass power is the fact that it has a much higher capacity factor compared to wind or solar. Furthermore, biomass systems are able to provide electricity on demand.

Figure 5 presents the type of biomass that is used for power generation in the EU-28. The dominant source is solid biomass, followed by biogas. Figure 6 presents the new biomass firing boilers with electric capacities higher than 5 MW; biomass use in existing fossil fuel fired boilers, e.g. "co-firing" amounts to 36 % of the new installed capacity since 2008.

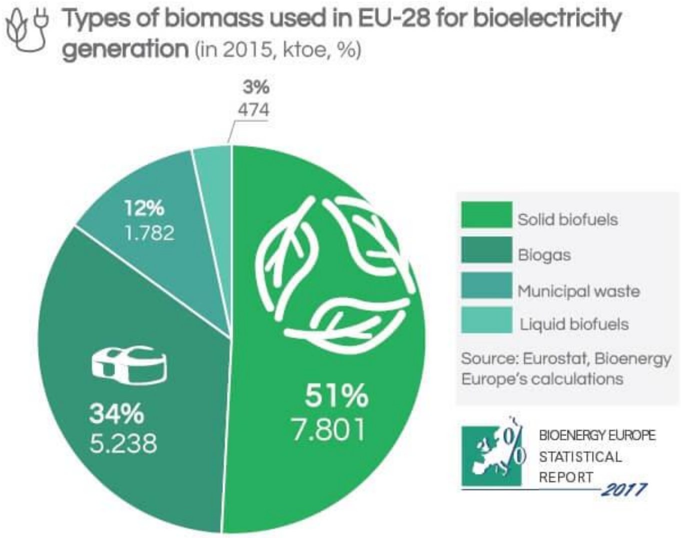


**Figure 5: Types of biomass used in EU-28 for bioelectricity generation (Source: Bioenergy Europe, 2019)**

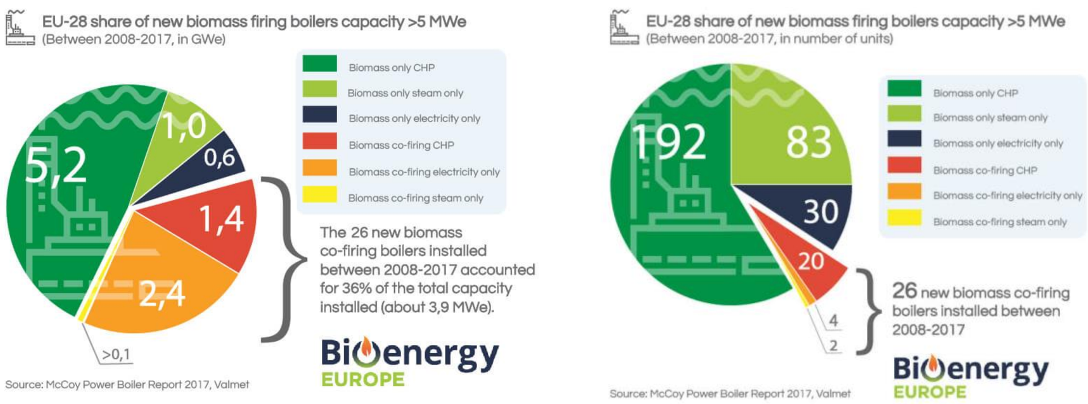


**Figure 6: EU-28 share of new biomass firing boilers capacity >5 $MW_{el}$ in $GW_{el}$ (left) and in numbers (right) (Source: Bioenergy Europe, 2019)**

## 5.2 Technical solutions for biomass integration

Integrating biomass in existing power or CHP plants effectively means substituting partly ("co-firing") or fully ("repowering") the thermal energy provided by the combustion of a fossil fuel, most commonly coal, with biomass.

There are different technical options to integrate biomass in an existing fossil-fired plant; the choice depends on the choice of biomass to be fired, the level of fossil fuel substitution as well as on the overall economics. In brief, they can be divided into the following categories:

- **Direct co-firing** is the simplest option to directly substitute coal with biomass, which is usually technically possible up to no more than 20 % on a fuel input basis. There are different technical options that can be considered, from simply mixing coal and biomass and using the existing coal feeding, milling and burning system, all the way to the installation of new feeding systems, mills and burners, specially designed for biomass. It is usually the simplest option to implement and the one with the lowest CAPEX expenditure. A wide range of biomass fuels is used in direct co-firing applications.

- **Indirect / gasification co-firing** implies a gasifier to turn solid biomass into syngas. The syngas is then fed into the fossil fuel boiler. This solution comes with higher flexibility and potential to co-fire higher shares of biomass but also with a higher CAPEX requirement due to the installation of a new gasifier.

- **Parallel co-firing** is the installation of a separate boiler for biomass combustion, which is connected to the fossil fuel boiler only by the steam cycle. Like indirect co-firing, the CAPEX requirement is quite high, but there are technical advantages in choosing this option.

- **Repowering** is the evolution of direct co-firing to very high shares of biomass in the fuel mixture, often up to 100 %. This option requires the change of the fuel feeding, milling and burning system to something suitable for biomass. There are several repowered coal-to-biomass power plants already in operation in Europe. The most common biomass fuel used in such projects is wood pellets, followed by wood chips.

- **Thermal pre-treatment of biomass** is an alternative to the options mentioned above. This technique pre-treats the biomass to transform its properties into something that closely resembles coal (e.g. higher heating value, easier milling, hydrophobic properties so that it can be stored in the open air, etc.). In this way, expensive retrofits in a coal power plant can be avoided and the pre-treated biomass fuel can substitute coal almost directly. There are several processes available to achieve this biomass transformation such as torrefaction, steam explosion or hydrothermal pretreatment.

## 5.3 Policy recommendations

Political will to reduce greenhouse gas emissions and a series of policy measures (e.g. the Emissions Trading Scheme) have severely limited the future perspectives of coal fired power plants within the European Union. A fuel switch from coal to biomass can be a way for European power industries to utilize “stranded assets” such as existing coal power plants during a transition period to full decarbonisation. There are various technical solutions available to implement such a retrofit. The chances of its implementation are affected by the following issues: a) availability of the biomass, b) policy framework, c) the national decarbonisation targets, d) the company strategies.

The revised Renewable Energy Directive has already created a more level playing field across the EU for such retrofits. A key point in the new Directive is that biomass co-firing projects with low biomass thermal shares will be effectively ineligible for support in the future.

Through this approach, the use of biomass for power and heat generation becomes disentangled from the continued use of coal.

Policy recommendations for the sector intend to ensure its role as a valuable component in the transition of the European energy system:

- **Recognize the role of biomass as an important feedstock for power generation in the differentiation of the EU energy mixture**. The European electrical grid is still in need of non-stochastic, thermal power generation. With the coal phase-out (and in some countries nuclear phase-out as well), this role is increasingly played by natural gas. Although "cleaner" than coal, natural gas is still a fossil fuel, contributing to GHG emissions, and increases the reliance of EU on imported energy sources. Biomass can assist in the differentiation of the energy imports or even reduce them if domestic resources are exploited; moreover, it is considered as carbon-neutral and is capable of producing significant and constant amounts of green energy for the grid.

- **Recognise coal to biomass retrofitting as a measure for the support of coal regions in transition.** The decarbonisation of the power sector is a serious challenge both on the European and national level, but also on the regional level. For Coal Regions in Transition, the closure of coal mines and power plants places a severe socio-economic pressure through the expected loss of jobs. Coal to biomass repowering projects can help these regions in the transition period to maintain their "energetic" character and industrial expertise, while also maintaining local jobs for the repowered plants' operation or the biomass logistics operations.

- **Promoting the use of local biomass resources.** Coal to biomass repowering projects require large volumes of biomass fuels, which are currently mostly coming from imported wood pellets. Although their use should not be disregarded, Europe has a significant potential of agrobiomass resources that can be effectively used for power and heat generation. There are specific technical challenges in using such resources as well as more organizational issues on setting up supply chains. Hence, special policy support should be encouraged for projects aiming to exploit such resources.

- **Promoting innovative projects and new emerging technologies.** Power production with biomass, coupled with Carbon Capture and Storage or Utilization (in short BECCS or BECCU) can potentially lead to negative carbon emissions in the European power sector. Such demonstration projects could be considered within the Innovation Fund (https://ec.europa.eu/clima/policies/innovation-fund_en) and / or evaluated under national strategic roadmaps.

- **Promoting increased heat utilization in large-scale facilities.** Large fossil fuel fired power plants are often designed and operated with low to no heat utilization. On the contrary, newly built biomass plants are often designed from the start as CHP units. Retrofitting projects should strive – to the extent possible – to maximize the overall fuel efficiency in order to ensure a better use of the biomass resources. The establishment of new heat demand, e.g. through the establishment of new industries and processes, can also be seen as a way to revitalize coal regions in transition. Such concepts are already being explored, e.g. by the ARBAHEAT H2020 project (https://www.arbaheat.eu/) which aims to transform a coal fired power plant into CHP by retrofitting and integrating a biomass upgrading process.

Beyond the European Union, in Energy Community countries[11], the potential for applying biomass co-firing or repowering is affected by the specific national framework conditions. The policy recommendations that would allow the increased market uptake of biomass in the sector are based on the same policies that have also facilitated the transitions within the framework of the European Union or specific member-states:

- Establishing a mechanism for carbon pricing, e.g. a carbon tax or a $CO_2$ emissions scheme;
- Promoting the share of biomass in the power and heat generation sector.
- Establishing mandatory shares of renewable energy in the power generation portfolio of utilities.

[11] The Energy Community is an international organisation which brings together the European Union and its neighbours to create an integrated pan-European energy market. The organisation was founded by the Treaty establishing the Energy Community signed in October 2005 in Athens, Greece, in force since July 2006. The key objective of the Energy Community is to extend the EU internal energy market rules and principles to countries in South East Europe, the Black Sea region and beyond on the basis of a legally binding framework. (www.energy-community.org)

# 6 Conclusion –outlook of the retrofitting options

This policy paper summarizes markets and technologies for retrofitting the 5 BIOFIT sectors and presents initial recommendations for policy makers. Thereby, it must be considered that the five sectors are very different and that recommendations must be formulated individually for the sectors. Nevertheless, two general observations are that (1) biomass availability and mobilisation play an important role in all sectors and require due attention, (2) there are many new technological opportunities for bioenergy retrofitting, leading to a wide spectrum of, high-value products, higher efficiencies and lower cost, which justifies continued support for RD&D as well as dedicated policy development.

The retrofitting of the **first-generation biofuels industry** with second generation biofuel technologies is needed in order to further develop the overall biofuels market in Europe. Although it is expected that electromobility will play a key role in the future transport sector, biofuels will be important to cover niche applications such as heavy duty transport or for the aviation sector. In addition, also first generation biofuels still have their justification and their use may be extended. This applies for instance to the small-scale production and use of pure plant oils and biodiesel for powering heavy machinery in the agricultural sector. Improved waste fat collection (with the appropriate regulations in place) could help generate more sustainable feedstock for biofuel production.

The **pulp and paper industry** already uses biomass for their main products. A distinction in the sector must be made in companies that only produce pulp, in companies that buy the pulp from other companies to produce paper products, and in companies that produce both, pulp and paper. Depending on this, biomass and waste products can be already used in some plants as process energy or even sold. As paper products will be needed in the long-term, the full retrofitting of the whole sector is sustainable and should be a political priority, with specific attention to non-pulp producing plants.

**Fossil refineries** still supplies the whole transport sector with energy, today, as fossil fuels are still the dominant energy source in the sector. However, policies on the decarbonisation of the energy sector will have a huge impact on fossil refineries and may lead to radical change of the industry. Partial retrofitting of refineries with biomass can be seen as an intermediate step in the short to medium term. In the very long-term, the refining of crude oil into various products will be non-existent as such or at least have only a very marginal role. Opportunities exist, however, if today's refineries are transferred into installations with different roles, services and products. Thereby, the full conversion into biorefineries and the use of new technologies such as Power-to-X and Synthesis processes can open up future windows for the refinery sector.

The **fossil power generation sector** is based on the large-scale use of coal, oil and natural gas. Similar to the fossil refinery sector, it faces the overall challenge of the decarbonisation targets. There exist several retrofitting options with bioenergy, that can be implemented in the short- to medium term. However, a key problem for these large-scale power units is its low overall fuel efficiency as the heat is not used. As general competition about biomass will increase in the future, the power generation without heat use will need to be phased out or replaced by CHP. The role of CCS/CCU for fossil power plants is related to various political uncertainties due to its environmental impacts and still unclear for the future.

The **combined heat and power (CHP) sector** includes small to large scale installations that are fuelled by fossil fuels or by biomass. For the larger scale CHP units that are fuelled with fossil fuels, the retrofitting options are very similar to those of the fossil power generation sector.

**For both, the fossil power and the large-scale CHP sectors**, a general challenge is the centralized location of the installations. In the future, it may be required to give up the central locations of large-scale units and to install more decentralized units which are located closer to the heat demand. This may be needed, due to the challenge of biomass logistics and to increase the fuel efficiency of biomass. The installation of several smaller new installations instead of sustaining the large installations has the advantage of being more suitable to balance intermittent power sources, such as solar and wind. Another challenge of both sectors, in case the installations are fueled with coal, is related to the phase-out of coal and its social challenges for the coal regions in transition. For these regions, coal to biomass retrofitting can be a supporting measure for the short-term.

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*Citation, Acknowledgement and Disclaimer*

Dominik Rutz et al., 2019, "Summary Paper for policy makers: retrofitting Europe's industry with bioenergy", Bioenergy Retrofits for Europe's Industry. BIOFIT, Horizon 2020 project no. 817999, WIP Renewable Energies, www.biofit-h2020.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n° 817999.