Technical assistance in realisation of the 5th report on progress of renewable energy in the EU

Task 3

State of play of bioenergy consumption in the EU and assesses the compliance of biofuels and bioliquids with the EU biofuel sustainability criteria through national certification or by voluntary schemes that have been recognised by the Commission.

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Technical assistance in realisation of the 5th report on progress of renewable energy in the EU

Analysis of bioenergy supply and demand in the EU (Task 3)

– Final report –

By: Navigant – A Guidehouse Company

Date: 5 October 2020

Project number: 210248

Executive summary

Scope

The Renewable Energy Directive requires the Commission to report on the progress of renewable energy and on the sustainability of biofuels consumed in the EU. To assist the Commission in this task, this report provides insights into the development of biofuels, biomass and biogas for renewable energy in the EU from 2010 to 2018 (with a focus on the most recent years). Specifically, the report assesses the production, consumption and trade of bioenergy, and quantifies the sustainability impacts of EU consumption of biofuels. The analysis is based on Member State Renewable Energy Progress Reports submitted in 2019[1], Eurostat SHARES and other Eurostat statistics, other reports, studies and databases, and additional original research.

Overview of bioenergy in the EU, and its main applications

In 2018, bioenergy represented the largest source of renewable energy in the EU, with a gross consumption of 145 Mtoe or 60% as shown in Figure S 1. The most important use of bioenergy is in the heating and cooling sector (84.6 Mtoe final energy), followed by electricity generation (16.2 Mtoe final energy) and transport (16.6 Mtoe fuels delivered).[2] The majority of liquid bioenergy comes from the use of biodiesel (75%).

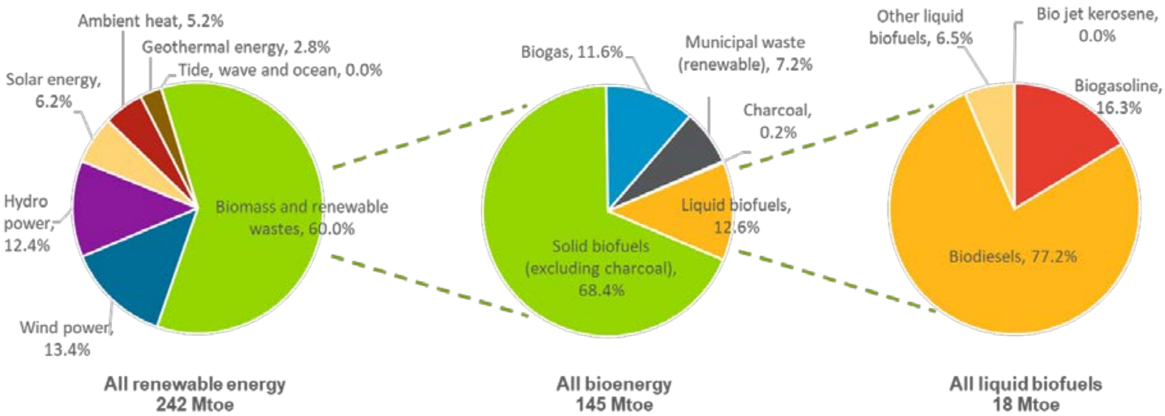

Figure S 1. Gross EU consumption[3] of renewable energy per type (2018, % and Mtoe). Source: Eurostat nrg_bal_c

Figure S 2 compares this consumption per sector to the indicative targets for bioenergy use in those sectors as laid out in the Member States' National Renewable Energy Action Plans (NREAPs). The generation of heat from biomass is close to the indicative NREAP targets. The gap is larger for electricity in relative terms (though smaller in absolute values). For biofuels, the gap is larger in both relative and absolute terms. Specifically, in the case of biofuels, the large gap does not per se imply that the 2020 indicative NREAP targets may be difficult to meet since the international production capacity for biofuels is larger than the target requires. Sufficient biofuel volumes can be bought on the market to fulfil the targets and, unlike electricity and heat production, no build-up of capacity is required.

[1] These reports have been published online and can be found here: https://ec.europa.eu/energy/en/topics/renewable-energy/progress-reports
[2] The difference between the total of final bio-energy consumption (117 Mtoe) and gross bio-energy consumption (140 Mtoe) is mainly due to the efficiency of electricity generation, while biofuel and bioheat retain most of the energy from the original biomass.
[3] Here, "consumption" is measured at the moment the biomass is consumed, e.g. in the production of heat or power, or as a fuel in transport.

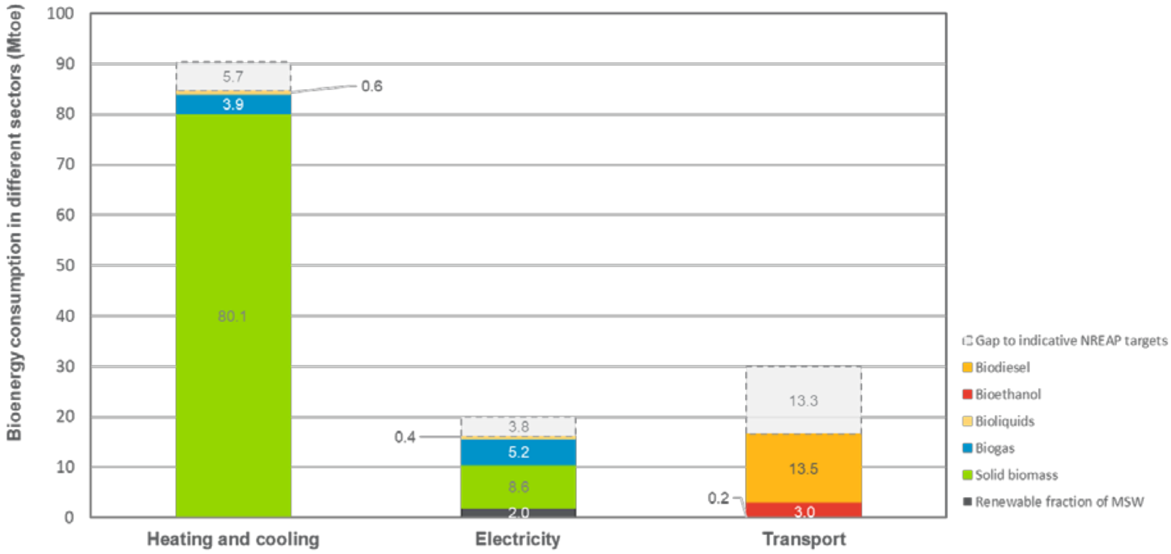

Figure S 2. Bioenergy consumption by end use in 2018 versus 2020 NREAPs targets (Mtoe)[4]

In the heating and cooling sector, by far the largest part of the bioenergy is produced from solid biomass, followed by biogas and a small amount of bioliquids. Solid biomass is also the main energy carrier in the electricity sector, followed by biogas, the renewable fraction of municipal solid waste (MSW) and a small amount of bioliquids. For the transport sector, mainly biofuels are used as the energy carrier.

Main bioenergy carriers

Solid biomass is the major bioenergy carrier used in the EU for bioenergy production (99 Mtoe gross consumption, delivering 88.6 Mtoe in final energy carriers). The main feedstock for solid biomass is forest biomass (91%, including fuelwood,[5] wood residues and by-products, wood pellets and black liquor[6]). Germany, France, Italy, Sweden, Finland and Poland show the largest consumption of fuelwood, wood residues and by-products. The consumption of black liquor is considerable in Sweden and Finland, which have large pulp industries. In some countries, energy crops and agricultural residues also play a significant role. Note that the available statistics do not give insight into which feedstock is exactly used in the production of bioenergy in each end-use sector.

The vast majority (90%) of solid biomass consumed in Europe's heat and power generation is sourced from within the EU. In 2018, the largest importer of wood pellets was the UK, responsible for almost 64% of EU imports. The most important third countries supplying wood pellets to the EU were the USA (almost 60%), Canada (17%) and Russia (13%).

Liquid bioenergy carriers form the second largest bioenergy carrier in the EU (18 Mtoe gross consumption, delivering 17.5 Mtoe in final energy carriers) represents 13% of all bioenergy, or 8% of all renewable energy (in all sectors). Liquid bioenergy mostly consists of biofuels in transport (13.5 Mtoe biodiesel and 3.0 Mtoe bioethanol), but also accounts for a small amount of so-called

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[4] Sources: Bioenergy in electricity generation based on Eurostat nrg_bal_c, bioenergy in transport based on Eurostat SHARES and nrg_bal_c, bioenergy in heating and cooling based on 2019 Member State reports and indicative NREAP targets based on analysis by ECN.

[5] Fuelwood (also known as wood fuel) is defined by the European Commission as "*Roundwood being used as fuel for purposes such as cooking, heating or power production. It includes wood harvested from main stems, branches and other parts of trees (where these are harvested for fuel) and wood that is used for the production of charcoal (e.g. in pit kilns and portable ovens), wood pellets and other agglomerates. It also includes wood chips to be used for fuel that are made directly (i.e. in the forest) from roundwood. It excludes wood charcoal, pellets and other agglomerates*." (see https://ec.europa.eu/knowledge4policy/glossary/wood-fuel_en).

[6] Eurostat includes black liquor in the category of solid biomass.

'bioliquids', i.e. liquid forms of bioenergy used for power production. These bioliquids are thought to mostly consist of vegetable oils and pyrolysis oil.

Biogas is the third largest bioenergy carrier in the EU (16.8 Mtoe gross consumption, delivering 9.3 Mtoe in final energy). It is mainly used for the generation of renewable electricity and heat.

The **renewable fraction of municipal solid waste** (MSW, 10.4 Mtoe gross consumption) is also a significant source of bioenergy, especially in the electricity sector (2.0 Mtoe final energy). Overall, the EU has experienced an increase in the use of MSW for bioelectricity generation since 2010. In 2018, Germany was by far the largest consumer of MSW for power generation, accounting for 27% of the EU consumption, followed by the UK (16%), Italy (10%), France (10%), the Netherlands (9%) and Sweden (7%).

Renewables in transport

For the transport sector, the share of renewable energy in 2018 reached 8.0%,[7] consisting of:

- 3,905 ktoe of Annex IX biofuels (double counted → 2.5%)[8]
- 12,692 ktoe of other compliant biofuels (single counted → 4.1%)
- 52 ktoe of renewable electricity in road transport (five times counted → 0.1%)
- 1,618 ktoe of renewable electricity in rail transport (two and half-time counted → 1.3%)
- 291 ktoe of renewable electricity in other transport modes (single counted → 0.1%)
- 0.04 ktoe of other renewable energy (single counted; <0.0%)

The largest part of renewable energy in transport is supplied by biofuels. About 35% of EU biofuel consumption is in France and Germany. The contribution of renewable electricity in rail (and other transport modes) has been growing slowly, mainly because of an increasing share of renewable electricity in the electricity mix. Electricity in road transport is small, but slowly increasing. The role of other forms of renewable energy in transport, for example in the form of hydrogen, is small.

After the strong growth in biodiesel consumption in the decade to 2010, consumption in the EU has been stable from 2011 to 2016, at between 11 and 12 Mtoe, with only a temporary dip in 2013. In 2017 and 2018, we again see an increase in biodiesel, with a consumption of 14.2 Mtoe in the EU in 2018. France, Germany, Spain, followed by Sweden and Italy are the largest consumers of biodiesel in the EU.

In 2016, 41% of biodiesel volume consumed in the EU market came from feedstocks that were produced in the EU, mainly from EU rapeseed (26%), UCO (8%), animal fat (5%), soybean (1%) and a small fraction that remains unknown. UCO biodiesel also originated from China, South East Asia, the USA and other countries. The UCO market has been dynamic and in 2017, China started playing an important role as a source of UCO biodiesel consumed in the EU. In addition, about 23% of the EU biodiesel volume stemmed from Indonesian (15%) and Malaysian (7%) palm oil.

EU bioethanol consumption showed a declining trend in the EU from 2011 to 2016 but picked up from 2016 to 2018. The largest consumers of bioethanol are Germany, France and the UK. About 73% of the bioethanol consumed in the EU in 2018 stems from feedstocks that are produced in the EU, mainly wheat (34%), maize (24%) and sugar beet (14%) and only a small amount from cellulosic ethanol. Non-EU origin feedstocks account for about 27% of the EU bioethanol market, mainly based on maize originating from Ukraine, Brazil, the USA and Canada.

All of the 28 Member States have implemented the Directive's sustainability criteria in their national legislation. Fifteen Member States reported that they have implemented the ILUC Directive already in national legislation (see Table 10). One Member State, Bulgaria, mentions that the implementation of

[7] Following the accounting method of the Renewable Energy Directive.
[8] Note that biofuels for transport, as defined in the Renewable Energy Directive, also include biogas.

the ILUC Directive has started in 2018. The other twelve Member States have not mentioned the ILUC Directive, or its national implementation, in their Progress Reports. They have however reported to the Commission that the ILUC Directive has been implemented.

Land used for biofuel production

Based on a statistical analysis, the land required for the production of EU consumed biofuels in 2018 is around 3.4 Mha within the EU and 3.8 Mha outside of the EU. This figure is likely higher than the actual area used, because conservative data has been used for the conversion efficiencies and yields. The 3.4 Mha of cropland used for the production of agricultural raw materials for biofuels consumed in the EU in 2018 equals 3% of the total EU cropland of 117 Mha. Rapeseed was the main crop used for biofuel production in the EU and represented 72% of the share of the total land used for biofuels production.

On a global level the share of cropland that was estimated to be used for feedstock production for EU biofuels is around 0.5%. For the main third countries providing feedstock for EU biofuel consumption (Indonesia, Malaysia and Argentina) it is estimated that their share of total cropland used for the extraction of feedstocks that were used in the production of biofuels produced or consumed in the EU is small. For Indonesia this was just over 1% of their total cropland, while for Malaysia and Argentina the land used to produce feedstock for biofuels produced or consumed in the EU, makes up 3.3% of the total cropland of these countries. As shown in section 4.4.2, Argentina is the largest exporter of biodiesel to the EU in 2018.

In contrast to these estimates, the Member State Progress Reports indicate a land use of about 17 Mha used for the production of crops for biofuels, about 59 Mha for short rotation trees and about 61 Mha for other energy crops. The difference is explained by the facts that

a) The land use reported by Member States covers crop production dedicated to total bioenergy use including solid, gaseous and liquid biofuels that are consumed in the electricity, heating & cooling and transport sectors combined, not just biofuels.
b) Responses sometimes included all land used for these categories of crops, not the share specifically dedicated to bioenergy purposes
c) There is not always a direct link to the extent the reported feedstocks are actually used for bioenergy purposes within the Member States. Therefore, the combined numbers as reported by the Member States are likely to be too high.

Environmental and socio-economic impacts of biofuels

The Member State Progress Reports indicate a total greenhouse gas emission saving of 45 Mtonne CO_{2eq} in 2018, which is a 14% increase in savings as compared to 2017. Independent analysis suggests a slightly smaller total greenhouse gas emission saving of 48.6 $MtCO_{2eq}$ based on the consumption of 17,200 ktoe of biofuels displacing the same amount of energy from fossil fuels. None of the Member States indicate if the reported greenhouse gas emission savings include or exclude ILUC emissions. It is impossible to accurately calculate the ILUC emissions per Member State, because this would require an exact insight into the feedstock composition per country, and in changing feedstock patterns over time (because ILUC is caused by additional demand and the exact impact changes over time). When the 2018 crop feedstock volumes are multiplied with the corresponding mean ILUC values from the ILUC Directive, this suggests that the emission savings from renewable energy in transport are reduced to 24.0 Mtonne CO_{2eq} (with a range of 18.8-33.8 Mtonne $CO2_{eq}$ when using the ranges from the ILUC Directive). This is however an underestimation of savings, caused by an overestimation of ILUC. The 2000-2010 (historic) ILUC emissions from EU grown crops are significantly lower than those for 2010-2020 reported in the ILUC Directive.

Most Member States ascertain that due to limited domestic feedstock production no significant environmental impacts are expected. Those Member States that produce the majority of EU biofuels affirm that the environmental impacts of crop production are expected to be the same regardless of the final end use sector, and that these impacts are regulated through horizontal environmental legislation (e.g. valid for the whole agricultural sector). Several Member States also refer to the voluntary schemes or national systems used to safeguard sustainability impacts, and therefore indicate limited sustainability impacts.

Additional analysis of possible direct environmental impacts related to biofuel feedstock production in the main third countries of supply shows that the geographical contexts covered in this report are quite heterogeneous and agricultural supply chains tend to be characterised by a high degree of site-specificity. This means that it is not always possible to say with certainty whether identified risks are present in the specific supply chains delivering feedstock for EU biofuels. However, the fact that crops used for EU biofuel feedstock must adhere to the sustainability criteria of the Renewable Energy Directive should mean that the risks of direct land use change are minimised. Indirect impacts are not addressed by the voluntary schemes.

In recent years no correlation has been observed between food prices and biofuel demand, and any impact is likely to be small compared to other dynamics in the global food market. Most Member States did not observe any impacts on prices due to increased bioenergy demand within their countries. In literature there are causes other than biofuel production identified for increased food prices in the period of the food price spikes in 2006–2008 and 2011.

IRENA estimates that globally, liquid biofuels employed 2 million in 2018, with the majority of jobs in planting and harvesting biomass feedstocks. For the EU, it is estimated that the biofuel industry employed 208,000 in 2018, making biofuels the third largest renewable energy job creator after wind energy and solid biomass (314,000 and 387,000). The countries with the greatest employment related to biofuels are Romania (40,000 jobs) and Poland (41,200 jobs) due to their large agricultural land area. France is the third largest (29,100 jobs) as it has both biofuel production facilities and feedstock production.

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Abbreviations

CHP	Combined Heat and Power
DME	Dimethyl Ether
EC	European Commission
ETBE	Ethyl Tert-butyl Ether
FAME	Fatty Acid Methyl Ester
GHG	Greenhouse Gas
HVO	Hydrogenated Vegetable Oil
ILUC	Indirect Land Use Change
ILUC Directive	DIRECTIVE (EU) 2015/1513
MS	Member State
MSW	Municipal Solid Waste
NGO	Non-Governmental Organisation
NREAP	National Renewable Energy Action Plan
RES Directive	Renewable Energy Directive (DIRECTIVE 2009/28/EC)
REDII	Recast of the Renewable Energy Directive (DIRECTIVE (EU) 2018/2001)
RES	Renewable Energy Sources
RES-H&C	Renewable Energy Share in Heating and Cooling sector
RES-E	Renewable Energy Share in Electricity sector
RES-T	Renewable Energy Share in Transport sector
Toe	Tonne of oil equivalent
UCO	Used cooking oil

Terminology for biofuels and their feedstocks

A large part of this report is about the sustainability of biofuels. Biofuels exist in many sorts and can be produced from many types of feedstocks. They can be produced via various technologies that already exist for centuries or that are invented rather recently. Biofuels are not automatically sustainable. In an effort to distinguish between different types of biofuels, stakeholders and individual organisations have applied some definitions that can be useful in casual discussions but that often lead to confusion. This is partially because these definitions are not mutually exclusive and collectively exhaustive. In other words, some types of biofuels could fall in multiple definitions and others fall in none. More importantly, the definitions suggest a level of sustainability quality, but the definitions are not suitable for this purpose. It is effectively impossible to classify types of biofuels or feedstocks and at the same time rank their sustainability performance.

Advanced biofuels versus conventional biofuels

These terms should be avoided. Most stakeholders relate the terms to the novelty of *technology*. However, some stakeholders relate these definitions to the type of *feedstock* and consider food crop-based biofuels as conventional. The 2015 ILUC Directive and the recast of the Renewable Energy Directive apply a feedstock-based definition and considers both waste and algae-based biofuels to be “advanced”. Stakeholders may assume that advanced biofuels are more sustainable than conventional biofuels, which is not necessarily correct.

First generation, second generation, etc.

These terms should also be avoided. Again, there is confusion over whether the terms should relate to the *technology* or the *feedstocks*. Following the trend, some emerging conversion technologies or feedstocks have been coined third or fourth generation. This causes further erosion of the already unclear definitions.

Definitions in this report

In this report, we apply the classifications and definitions that are specified by the European Renewable Energy Directive of 2009, because this report serves to assist the EC in their reporting obligations vis-à-vis this Directive. The Renewable Energy Directive has been amended by the ILUC Directive in 2015, which, in response to concerns about Indirect Land Use Change (ILUC) introduced new categories and definitions.

On the one hand, the ILUC Directive limits the contribution of biofuels that are often associated with Indirect Land Use Change. On the other hand, the ILUC Directive sets a specific sub target for biofuels that are assumed to have a low risk to cause ILUC. The 2018 recast of the Renewable Energy Directive (REDII) applies similar categories and a sub target. Note that (again) the categories cannot be used to understand the true sustainability performance, they merely indicate a high or low risk and a subsequent preference of the policy makers.

Therefore, the following categories are used throughout the report:

- The ILUC Directive states that “biofuels produced from cereal and other starch-rich crops, sugars and oil crops and from crops grown as main crops primarily for energy purposes on agricultural land shall be no more than 7% of the final consumption of energy in transport in the Member States in 2020.” In the frame of this report, we abbreviate this category to **“Crop based biofuels”**. Their contribution is limited to 7% points of the overall 10% target in 2020. Note that the recast of the Renewable Energy Directive simplifies this category to “food or feed crops” and at the same time makes the limitation dependent on the 2020 achievement per Member State, while low ILUC risk biofuels can contribute outside the 7% cap.
- The contribution of biofuels produced from feedstocks listed in Annex IX is not limited for the reporting until 2020. The recitals of the preamble of the ILUC Directive clarify that these biofuels are considered to be “advanced” and that they “provide high greenhouse gas emission savings with a low risk of causing indirect land-use change, and do not compete directly for agricultural land for the food and feed markets.” Biofuels produced from feedstocks listed in Annex IX count twice towards the target and are commonly called **“double counting biofuels”**. Annex IX consists of two parts:
  - Annex IX A contains a long and diverse list of feedstocks that are considered to be more advanced and the Directive sets an indicative target of 0.5% points for 2020. In the frame of this report we abbreviate biofuels produced from feedstocks in this category to **“Annex IX A biofuels”**. Note that the recast of the Renewable Energy Directive sets a lower initial target of 0.2% in 2022, increasing to 1% in 2025 and at least 3.5% by 2030 (after optional double counting).
  - Annex IX B concerns used cooking oil and animal fats categories 1 and 2. In the frame of this report we abbreviate biofuels produced from feedstocks in this category to **“Annex IX B biofuels”**. Note that the recast of the Renewable Energy Directive introduces a cap of 1.7% for this category (except for Cyprus and Malta).
- Feedstocks not listed in Annex IX that are “determined to be wastes, residues, non-food cellulosic material or ligno-cellulosic material by the competent national authorities and are used in existing installations prior to the adoption of [the ILUC] Directive” may also be counted towards the national target. This implies some additional freedom in the interpretation of this category.

Terminology for biomass for all energy purposes

Some forms of biomass can be used to produce multiple forms of energy. In this report, the following definitions apply:

- **Solid biomass** covers solid organic materials of biological origin and relates to the physical state before conversion. Solid biomass can include both forest and agricultural products, by-products and wastes. In this report, solid biomass is a product aggregate covering fuelwood (such as firewood, chips, pellets, logs), wood residues and by-products, black liquor, bagasse, animal waste and other vegetal materials excluding charcoal and the renewable fraction of municipal solid waste (MSW). This report only concerns solid biomass that is used as fuel for heat (and possibly cooling) production or electricity generation. Energy statistics of Eurostat uses “solid biofuels” term for presenting solid biomass. Since “biofuels” in the frame of the Renewable Energy Directive are associated with liquid fuels for transport this term should be avoided.

- **Biogas** is gas produced from biomass, mostly via anaerobic digestion and possibly (in future) via gasification and methanisation. Biogas also covers (pure) biomethane. This gas is currently used either for the generation of heat and power, or it is upgraded to natural gas quality and injected into the gas grid. There is increasing interest to use this biogas as a fuel for transport. In the statistical reporting of biofuels for transport in this report, biogas is inherently included, see below. We aim to clarify this were relevant.

- **Bioliquids** relates to the physical state of a biomass energy carrier. The term is only used for liquid biomass that is used to produce power and heat (and possibly cooling). It is likely to include vegetable oil, or pyrolysis oil. From a chemical and physical point of view, these materials could also be biofuels. Hence, the application is essential in the definition of bioliquids.

- **Biofuels** are liquid and gaseous types of bioenergy, for use in the transport sector, thereby replacing fossil gasoline, diesel or other fossil energy carriers.

Terminology for renewable energy in transport

According to the Renewable Energy Directive, the following energy carriers (when used in transport) count towards achieving the 2020 10% target for renewable energy in transport:

- **Biofuels**, with different types as explained above.
- **Renewable hydrogen**, that is hydrogen originating from renewable sources and it virtually does not exist yet in the EU. The two main production pathways are electrolysis based on renewable electricity and gasification of biomass.
- **Renewable electricity**.
- **Biogas**, as explained above is considered to be a biofuel by the Renewable Energy Directive. Please note that this is no longer the case for the REDII.
- **Fuels produced from renewable electricity** (via power-to-gas or power-to-fuels technologies) are not specifically mentioned in the Renewable Energy Directive, but in principle allowed. They hardly exist yet.

The renewable energy can be applied in all forms of transport (road, rail, shipping and aviation). In practice, most of the biofuels are still applied in the road sector.

1 Introduction

In 2009, the European Union adopted the first Renewable Energy Directive (also known as the RES Directive, or RED I). This Directive established an overall renewable energy target of at least 20% in final energy consumption for the EU (which is broken down in national targets) and a 10% target of renewable energy in transport for 2020 (which is the same for each Member State). The Directive requires Member States to implement policies and measures to reach these targets, and it includes EU binding sustainability criteria for biofuels and bioliquids. Member States were required to transpose the Directive into national legislation by 5th December 2010.

The Renewable Energy Directive (Article 22) requires Member States to report every two years to the European Commission on progress in the promotion and use of renewable energy and on the sustainability of biofuels. The reports cover, amongst others, the aspects listed in Article 22 of the Renewable Energy Directive. Member States are also required to deliver other information to the Commission, for example Article 18(3) requires that Member States submit aggregated information based on the data submitted by economic operators (compliance with sustainability criteria, and methods of verification).

Subsequently, Article 23 requires the Commission to report on the progress in renewable energy and on the sustainability of biofuels consumed in the EU. This report should be based amongst others on the information submitted by the Member States. The Commission is also required to monitor the origin of biofuels and their feedstock and several upstream sustainability effects, as well as displacement of land use, impacts on commodity prices and on food security. This 2020 report on renewable energy is the next report under this reporting obligation.

The current report aims to provide technical assistance to the Commission in realisation of the 2020 report on renewable energy. This report presents data collected and results of analysis on the EU biofuel, biomass and biogas markets and on impacts of the EU consumption of biofuels, biomass and biogas. This analysis is based on Member State's Progress Reports submitted in 2019, SHARES and other Eurostat statistics, other reports and studies, and additional research.

The Renewable Energy Directive has been amended by the ILUC Directive (Directive 2015/2013) in 2015 in response to concerns about Indirect Land Use Change (ILUC) impacts associated with food and feed crop-based biofuels. The ILUC Directive introduced new categories related to renewable energy in transport and limitations to the contribution of some types of biofuels. In 2018, the Renewable Energy Directive (REDII) was recast, now covering the period 2021-2030. In the transport sector, this recast Directive, for instance, promotes the deployment of advanced biofuels (defined on basis of feedstock listed in Annex IX A of that Directive). Although the recast Directive is not directly relevant for the 2017-2018 reporting period, it already starts to impact the market because producers, national policymakers and other stakeholders consider the post 2020 regulatory situation for their actions in the current market.

Chapter 2 presents an overview of bioenergy consumption in the EU in the main end-use sectors, with insights into the main feedstock categories. The bioenergy consumption in each sector is compared to the indicative targets as laid down in the National Renewable Energy Action Plans (NREAPs). Also, the role of biofuels in the frame of the 2020 target for renewable energy in transport is evaluated.

In Chapter 3, the supply of bioenergy, including the main forms of bioenergy and their origin, are assessed, except for biofuels.

The feedstocks of biofuels and their geographical origin are assessed in more detail in Chapter 4.

Building amongst others on the understanding of the geographical origin of biofuels and their feedstocks, Chapter 5 analyses the environmental impacts related to biofuels consumed in the EU.

The chapter presents details on land use, greenhouse gas emission savings and impacts on air, soil and water. This chapter also discusses how sustainability is safeguarded.

In Chapter 6, the economic and social impacts related to biofuels consumed in the EU are assessed, including the impact on food security, employment and impacts on other biomass using sectors.

6.3Appendix A and 6.3Appendix B present information as reported by Member States in their Progress Reports[9], on the biodegradable fraction of municipal solid waste and on the availability and use of biomass.

In 6.3Appendix C, more details are provided on the local environmental impacts from the main crop-country combinations that supply to the EU biofuels market.

Appendix D and E give an overview of the numbers underlying the graphs in respectively chapter three and four.

[9] Available at https://ec.europa.eu/energy/en/topics/renewable-energy/progress-reports

2. Bioenergy in the EU

Key findings

Bioenergy represents 60% of the 2018 EU gross renewable energy consumption. The 145 Mtoe of gross bioenergy delivers a net 85 Mtoe of heat, 16 Mtoe of electricity and 14 Mtoe of biofuels for transport.

Bioheat is mainly generated from solid biomass, including residues from forest management and by-products and waste from forest-based industries. Over half of the bioelectricity is also generated from solid biomass, while biogas delivers about 32%. In contrast, bioenergy in transport is primarily generated from biofuels, including biodiesel and a smaller fraction of bioethanol.

The generation of heat from biomass is quite close to the indicative national sectoral targets set out in the National Renewable Energy Plans (NREAPs), while the gap for electricity is smaller in absolute numbers, but larger in a relative sense. The gap towards reaching the NREAPs observed for bioenergy in transport has decreased from 15.8 Mtoe in 2016 to 13.3 Mtoe in 2018, but still remains large. In principle, a sufficient volume of biofuels can be obtained from the (global) market, and the gap could be closed quickly if demand was stimulated.

2.1 Overview

The majority of gross renewable energy consumption in the EU in 2018 consists of bioenergy (145 Mtoe or 60%), followed by hydropower (13%), wind (12%) and solar (6%), see Figure 1[10].

The fraction of bioenergy in final renewable energy consumption is smaller because the conversion efficiency to electricity is less than 100%. This is further explained in Section 2.2. Although the consumption of biomass and renewable waste in 2018 has grown by 4% compared to 2016 in absolute terms, its share of gross renewable energy consumption has decreased. This is caused by solar and wind energy growing at a faster rate. In addition, in the 2018 version of this report, ambient heat was not included in the total renewable energy consumption. Since data on ambient heat consumption is now available in Eurostat and consumption is significant at 5% of the gross renewable energy consumption, this has been included in Figure 1.

The growth of renewable energy consumption in the category 'biomass and renewable waste' is mainly caused by the growth in liquid biofuels, of which biodiesels have shown the fastest growth.

[10] Data in this section is based on Eurostat nrg_bal_c, unless specified otherwise.

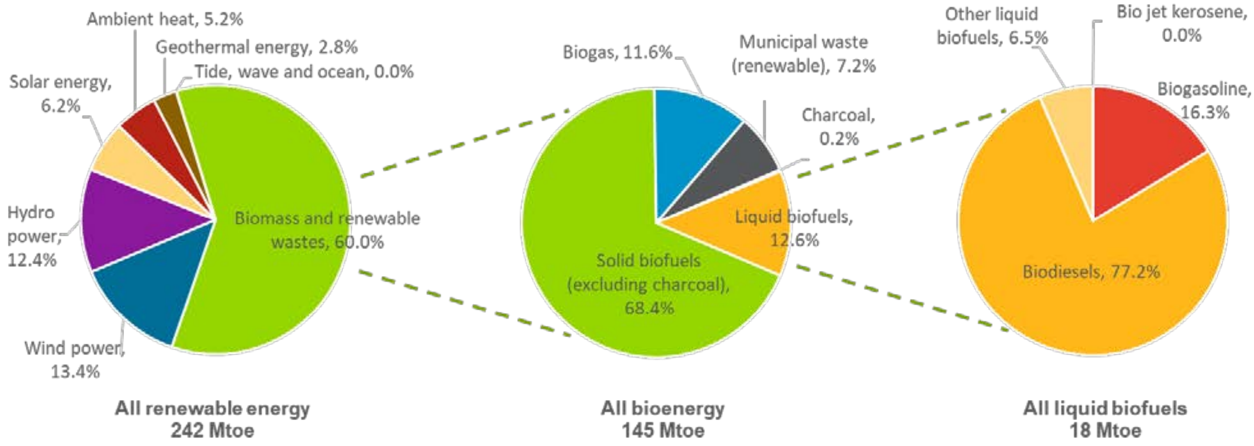

Figure 1. Gross EU consumption[11] of renewable energy per type (2018, % and Mtoe).[12] Source: Eurostat nrg_bal_c

Approximately 58% of the EU gross bioenergy consumption served to generate heat, followed by 11% to generate power, while 11% was consumed in the form of biofuels for transport (see Figure 2).[13] Germany was the largest consumer of bioenergy (27.1 Mtoe) followed by France (18.4 Mtoe), Italy (16.0 Mtoe), Sweden (13.6 Mtoe) and the UK (13.5 Mtoe).[14]

The progress of these sectors (heat, power, transport) compared to the combined indicative targets in the National Renewable Energy Action Plans (NREAPs) is discussed in Section 2.2.

2.2 Progress towards the indicative 2020 NREAP targets

Figure 2 presents the forms of bioenergy contributing to each of the three end-use sectors of heat, power and transport at an EU level in more detail. It compares bioenergy generation in 2018 to the sum of 2020 indicative targets set out in all Member States NREAPs. The 145 Mtoe of gross bioenergy delivers *net* 85 Mtoe of heat, 16 Mtoe of electricity and 17 Mtoe energy in transport. The total of this *net* energy is 117 Mtoe. Note that the difference is mainly driven by the efficiency of electricity production, as the efficiency of producing heat is close to 100%, and the gross bioenergy consumption in transport is expressed as fuels delivered to vehicles.

The figure shows that the generation of heat from biomass is rather close to the sum of the 2020 indicative national sectoral targets set out in the National Renewable Energy Plans (NREAPs), while the gap is *relatively* larger for electricity. For biofuels in the transport sector, the gap is large in both relative and absolute terms, however, the large gap does not imply per se that the 2020 indicative NREAP targets may be difficult to meet. In fact, the EU has more production capacity than necessary to bridge the gap, and an even larger supply potential exists in the global market. Therefore, the additional volume could in principle be delivered within a year.

[11] Here, “consumption” is measured at the moment the biomass is consumed, e.g. in the production of heat or power, or as a fuel in transport.
[12] The definitions of materials in this dataset slightly differ from those in the Renewable Energy Directive. Eurostat nrg_bal_c provides annual data on the “Supply, transformation and consumption of renewable energies”. The category “solid biofuels” (excluding charcoal)” in the Eurostat data coincides with “solid biomass” (term consistent with the terminology used by the Directive). Further note that biogas is partially produced from the wet organic (and renewable) fraction of municipal solid waste. In that case it is included in the biogas category, and not (anymore) in the waste category. Also, it is important to understand that the rightmost category of biofuels does not contain biogas, while part of the biogas in reality can be used for transport. Finally, the category “other liquid biofuels” largely overlaps with what the Directive calls “bioliquids”, i.e. liquid bioenergy carriers used for heat or power (not used in transport), but also contains a tiny fraction that is being used in transport. More precise insights into the use of bioenergy (and other forms of renewable energy) in transport are presented later in the report.
[13] The remaining 19% is due to losses along the supply chain and due to transformation efficiencies.
[14] Eurostat nrg_bal_c.

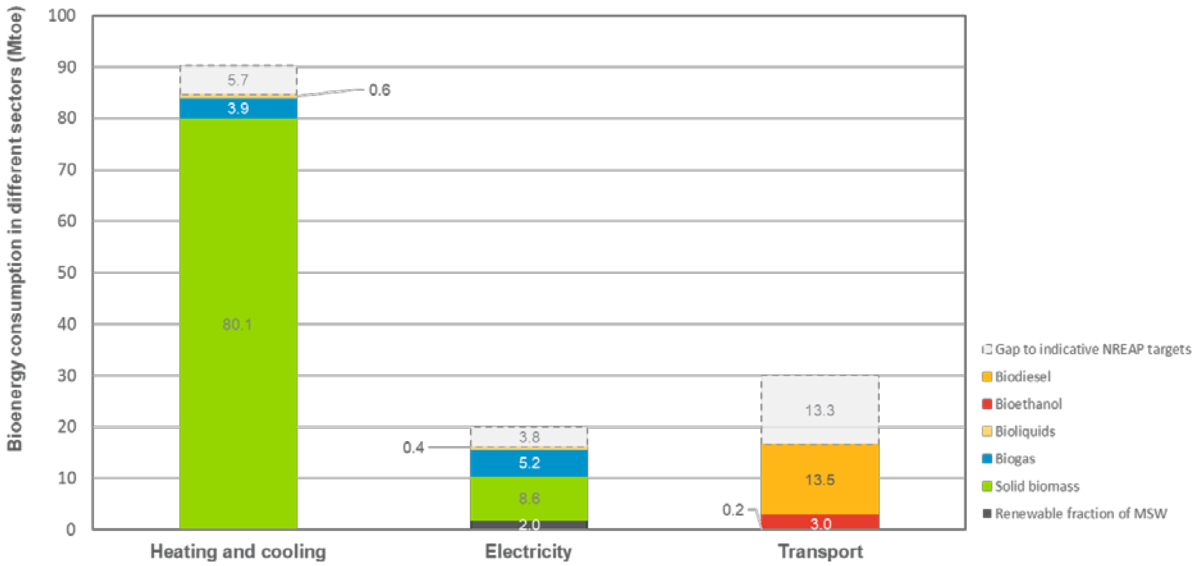

Figure 2. Bioenergy consumption by end use in 2018 versus 2020 NREAPs targets (Mtoe)[15]

[15] Heating and cooling are reported as final consumption, i.e. the amount of heat and cold effectively delivered. Electricity is reported as gross electricity generated. Fuels in transport are reported as final consumption, which implies the energy contained in the biofuels and biogas delivered to vehicles. Sources: Bioenergy in electricity generation is based on Eurostat nrg_bal_c, bioenergy in transport is based on Eurostat SHARES and nrg_bal_c. Note that Eurostat nrg_ reports on the supply, transformation and consumption of renewable energies, and contains details on the use in transport, distinguishing technical variations: biogas, biogasoline, biodiesels, other liquid biofuels and bio jet kerosene. However, these definitions do not comply with the Renewable Energy Directive, and it is unclear in how far these fuels comply with the Directive's requirements. On the other hand, Eurostat SHARES specifically reports on the deployment of renewable energy in the frame of the Renewable Energy Directive. SHARES gives details on the deployment of biofuels in transport, distinguishing between compliant biofuels and non-compliant biofuels (and some subcategories), but this dataset does not distinguish between technical variations. In this chart the total of compliant biofuels reported in SHARES has been combined with the technical fractions reported in nrg_bal_c. Bioenergy in heating and cooling is based on 2019 Member State Reports. Eurostat nrg_bal_c reports on the Supply, transformation and consumption of heat. It reports a total gross heat production from solid biofuels, biogases, biodiesels, other bioliquids and from the renewable fraction of MSW of only 14.8 Mtoe in 2018. This is much lower than what is reported by the Member States in their renewable energy Progress Reports (85 Mtoe in 2018). We do not know the reason for the large difference between Eurostat and what Member States report. It is also instructive to consider the Eurostat SHARES dataset, which reports on renewable energy in the frame of the Renewable Energy Directive. For heating and cooling, it does not specify the contribution of bioenergy, but reports that the final consumption of renewable energy in heating and cooling is 75.9 Mtoe and the amount of (additionally) "derived heat" is 15.1 Mtoe (and heat pumps amount to 12.0 Mtoe). Understanding that renewable heating and cooling mainly concerns bioenergy and that other options are largely limited to solar heating, we think the total of bioenergy in heating and cooling can be expected to be close to the 91.0 Mtoe total in SHARES. Hence, in this chart, the amount of bioenergy for heating and cooling has been based on the Member State Progress Reports. Indicative NREAP targets are based on ECN collection of data provided in the Member State National Renewable Energy Action Plans (NREAPs) available via www.ecn.nl/nreap (update 2011).

The development of bioenergy in the three sectors over time is shown in Figure 3, where it is compared to the sum of indicative sectoral NREAP trajectories. The development of bioenergy for heating in the EU has been continuously ahead of the trajectory, but the volume has stabilized since 2017, decreasing the gap with the trajectory. To reach the 2020 NREAP target for bioheat, a compound annual growth rate of 3.2% is needed, while the annual growth rate over the period 2014-2018 has been 3.8%. The development of biobased electricity generation has been on track, but since 2015, the growth has been too slow to keep up with the trajectory. In 2018, 16.2 Mtoe of electricity was produced from bioenergy, while the indicative sectoral NREAP trajectory lies at 17.6 Mtoe. To reach the 2020 NREAP targets for bioelectricity, a compound annual growth rate of 11.1% is needed, while the annual growth rate over the period 2014-2018 has only been 3.1%. The development of biofuels in transport has been continuously behind trajectory. Therefore, the total contribution of bioenergy does not reach the sum of the sectoral trajectories. To reach the 2020 NREAP target, a compound annual growth rate for bioenergy in the transport sector of 34% is needed, while this rate has been 7.9% over the period 2014-2018.

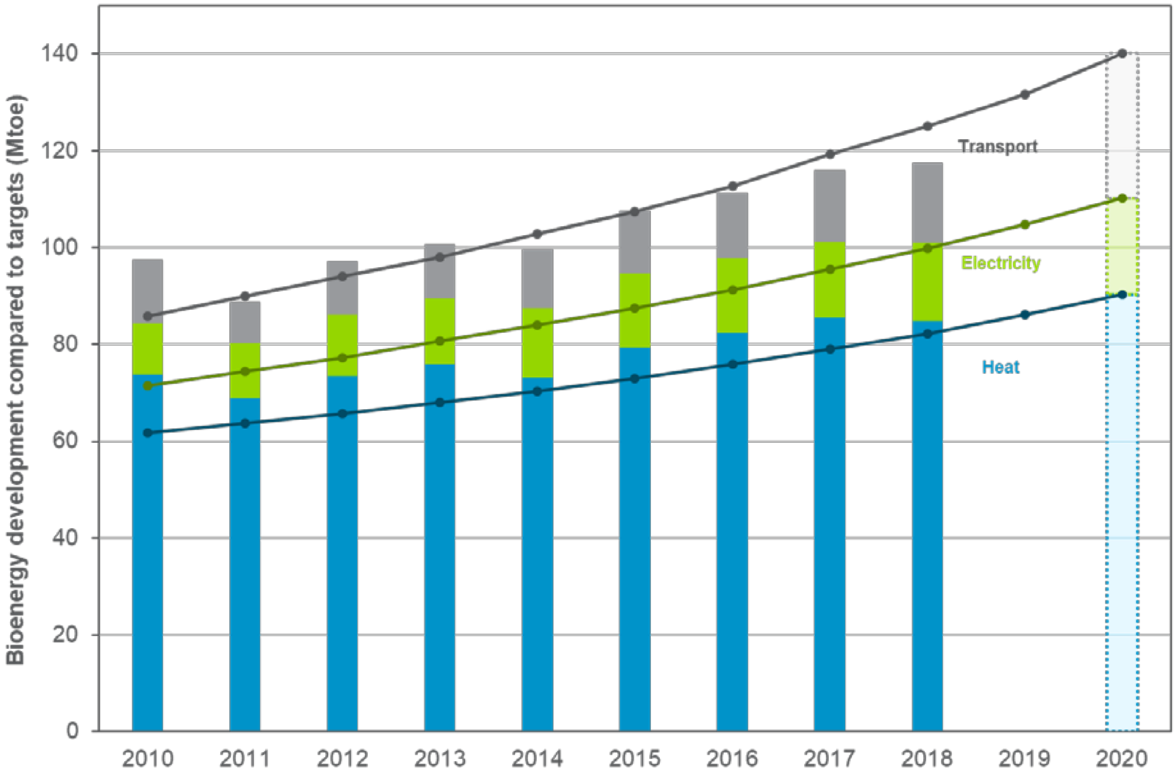

Figure 3. Development of bioenergy consumption per subsector in the EU (bars for the years 2010-2018) and compared to the sum of indicative NREAP trajectories (lines) and 2020 NREAP targets (bar)[16]

2.2.1 Bioenergy in Heating and Cooling

In practice, bioenergy for heating and cooling concerns only heating.[17] This heating is mainly produced from solid biomass (95%), as indicated in Figure 2 (Section 2.2). There was also a small contribution from biogas (4.7%), and an even smaller one from bioliquids (0.7%). Figure 4 shows details per Member State.

[16] Note that bioenergy in heating and cooling and transport are reported as "final consumption", in electricity is reported as "gross electricity generation" Sources: Bioenergy in electricity generation based on Eurostat nrg_bal_c, bioenergy in transport based on Eurostat SHARES and nrg_bal_c, bioenergy in heating and cooling based on 2019 Member State reports, and indicative NREAP targets based on analysis by ECN. See footnotes at the caption of Figure 2 for more information on these sources.

[17] The generation of cooling based on bioenergy was not observed, although trigeneration systems can use biomass combustion. Cooling on basis of renewable electricity can of course involve bioenergy.

Germany (14% of EU total) and France (12%) consume the most heating from bioenergy, followed by Sweden, Italy and Finland (all 9%). In most Member States, the deployment of bioenergy in heating in 2018 is already close to their 2020 indicative NREAP sectoral targets. France and Sweden, however, still face a large gap between the 2018 achievement and their indicative NREAP sectoral target. For the EU as a whole, a compound annual growth rate of 3.2% is needed for the period 2018-2020 to reach the 2020 NREAP target. This is slightly below the 3.8% compound annual growth rate seen for bioenergy in the heating and cooling sector in the period 2014-2018, but growth will have to pick up again as volumes have stabilised from 2017 to 2018.

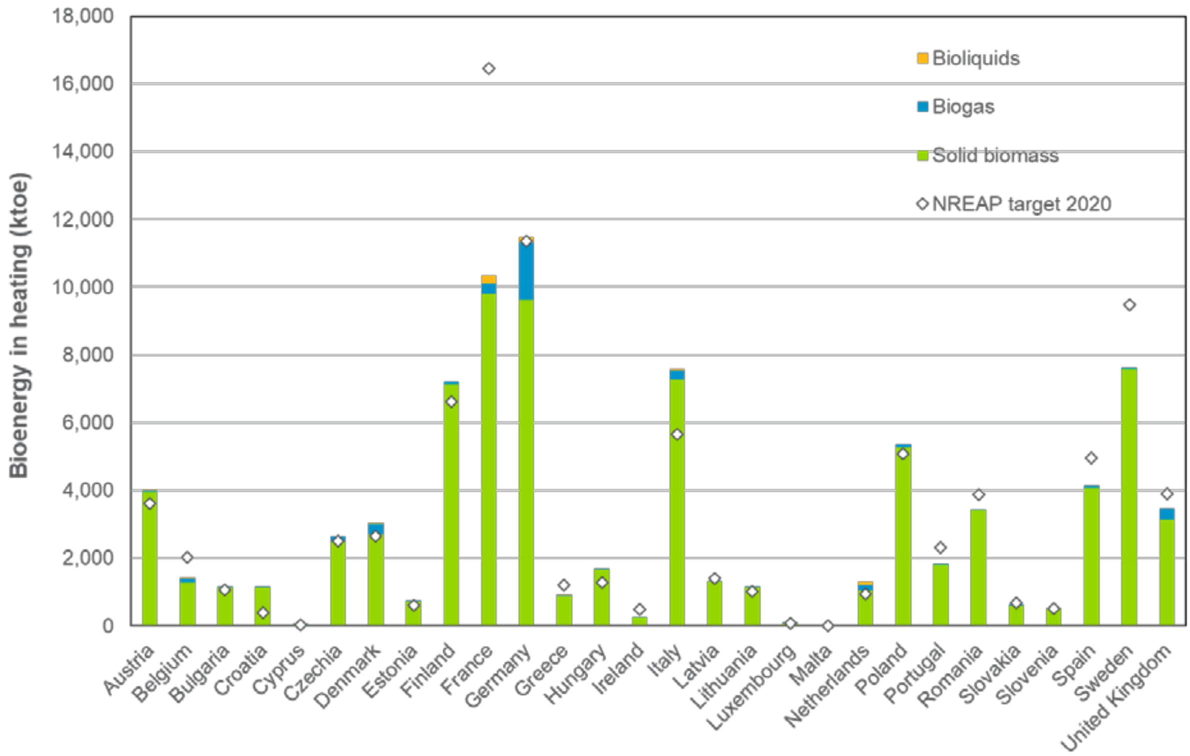

Figure 4. Bioenergy consumption in heating versus NREAP[18] (2018, ktoe). Source: MS Progress Reports, ECN[19]

As bioenergy for heating is mainly produced from solid biomass, the largest consumers of biobased heating are also the largest consumers of solid biomass: Germany, France, Sweden, Italy and Finland. All of these five countries rely on more than 80% domestic production of solid biomass consumed for heat *and power* generation. For the total EU, domestic production of solid biomass is 90% of the total market, which is discussed in more detail in Section 3.1.2. It is not possible to provide separate insights into the sourcing for both applications (heat and power). The largest biomass importer was the UK, responsible for 64% of EU wood pellet imports (8.5 million tonnes), of which the majority (7.8 million tonnes) was for power production at Drax and Lynemouth power plants.[20]

The most important third countries supplying wood pellets to the EU were the USA (close to 60% of imports), Canada and Russia (about 15% of imports each). A more detailed analysis of the EU production and consumption of solid biomass, feedstocks and their origins is presented in Section 3.1.

Biogas in the EU is primarily produced by anaerobic digestion of waste streams. Almost half of the heating based on biogas occurs in Germany and is mainly generated by farm based anaerobic digestion. Crops such as maize, sugar beet and cereals are used as co-digestate at farm level. It is

[18] 2020 indicative NREAP sectoral targets for bioenergy in heating.
[19] www.ecn.nl/nreap (update 2011).
[20] Bioenergy Europe Statistical Report (Pellet) 2019 – Bioenergy Europe and European Pellet Council

also possible to produce biogas via gasification of solid biomass, but this was not done at a commercial scale in 2018.

There is insufficient data to understand the origin of the feedstock for digestion. However, it is not economic to transport feedstock for digestion over large distances and therefore it can be assumed that all feedstock was sourced from the EU.[21] In terms of consumption, all the biogas produced in the EU was consumed domestically. A more detailed analysis of biogas is given in Section 3.2.

The small use of bioliquids for heating is mainly located in France (43%), Germany (31%) The Netherlands (15%) and Italy (8%). The exact nature of these bioliquids is unknown. They likely concern mainly vegetable oils and crop-based biofuels similar to those used in transport, and some pyrolysis oil.

2.2.2 Bioenergy in Electricity generation

At the EU level, the contribution of bioenergy to renewable electricity has increased in absolute terms, but slightly decreased in relative terms to approximately 18% in 2018, after remaining stable around 19% between 2012 and 2016 (see Table 1). This is caused by the faster growth of the total renewable electricity generation, driven by the strong growth in solar and wind power.

Until 2015, the total bioelectricity consumption grew with annual growth rates above 6%. In the years following, growth slowed to rates below 3%, with 2.6% in 2018. To reach the 2020 NREAP target of 20 Mtoe,[22] a compound annual growth rate of 11% is needed for the period 2018-2020.

In 2018, bioenergy was the third largest contributor of all forms of renewable electricity, behind hydropower (36%) and wind energy (36%), and ahead of solar power (12%). The share of bioenergy in total power production increased between 2012 and 2018. This was primarily caused by an increase in bioelectricity production, combined with a decrease in overall power production. Although total power generation has been increasing since reaching a lowest point in 2014, the generation of bioelectricity has grown faster in comparison.

Bioelectricity is sourced primarily from solid biomass (8.6 Mtoe in 2018) and biogas (5.2 Mtoe). The renewable fraction of municipal solid waste (MSW) has a smaller role (1.0 Mtoe) and bioliquids are negligible (0.4 Mtoe). The following table shows that both in absolute and in relative terms, biogas and solid biomass were the main drivers of growth in bioelectricity.

[21] Part of the feedstock for biogas production is considered to be waste (such as manure) and it is not economically attractive to import. The original commodities from which the waste was ultimately produced may have been imported, but this is not relevant for the current analysis. Note that co-digestion of crops could in principle be done with imported crops, but this is highly unlikely since anaerobic digestion takes place decentral, for instance at farms and it would not be competitive to bring imported crops “back” to farms for biogas production.
[22] Indicative NREAP target based on ECN collection of data provided in the Member State National Renewable Energy Action Plans (NREAPs) available via www.ecn.nl/nreap (update 2011).

Table 1. Bioelectricity consumption (2012 - 2018, ktoe). Source: Eurostat SHARES, Eurostat nrg_bal_c[23]

	2012	2013	2014	2015	2016	2017	2018
Solid biomass	6,758	6,906	7,270	7,867	7,905	8,150	8,555
Biogas	4,048	4,629	4,969	5,181	5,280	5,306	5,247
Renewable fraction of MSW[1]	1,577	1,600	1,694	1,771	1,818	1,908	1,973
Bioliquids[2]	303	369	414	473	455	429	423
Total bioelectricity	**12,686**	**13,504**	**14,348**	**15,291**	**15,459**	**15,793**	**16,198**
Total of renewable electricity	66,430	70,997	75,074	79,966	82,562	86,476	90,285
Total generated power	282,937	280,325	273,745	277,718	279,863	281,648	281,598
Share of renewable energy in power sector (%)	23.5%	25.3%	27.4%	28.8%	29.5%	30.7%	32.1%
Share of bioenergy in renewables total (%)	**19.1%**	**19.0%**	**19.1%**	**19.1%**	**18.7%**	**18.3%**	**17.9%**
Share of bioenergy in power sector total (%)	**4.5%**	**4.8%**	**5.2%**	**5.5%**	**5.5%**	**5.6%**	**5.8%**
Growth from previous year (%)	**11.5%**	**6.4%**	**6.2%**	**6.6%**	**1.1%**	**2.2%**	**2.6%**

[1] MSW: Municipal Solid Wastes
[2] Sum of biodiesel and "other bioliquids" (presumably this includes raw vegetable oil and pyrolysis oil).

Figure 5 shows the total bioelectricity consumption by Member State. Germany (27% of EU total) is the largest consumer of bioelectricity, followed by UK (17%) and Italy (10%). These Member States have already achieved their 2020 indicative NREAP targets, however, many others still face a large gap between the 2018 achievement these targets. The largest absolute gaps between the 2018 achievement and the indicative 2020 sectoral NREAP targets are seen in The Netherlands, France and Poland. However, in the Netherlands, solid biomass for bioenergy production (wood chips and pellets) is expected to increase by 500,000 tonnes from 2018 to 2020 based on allocated national subsidies.[24]

Some biomass power plants that have been granted subsidies have not yet started bioelectricity production due to delays caused by public opinion. In the first four months of 2020 bioelectricity production was approximately 190 ktoe[25]. If extrapolated to the remaining eight months, this would imply 570 ktoe in 2020, which is well below the NREAP projection. In Poland's NREAP projections, biogas needs to grow 168% from 2017-2020 compared to only 8% for solid biomass.[26] Although there are quite some current developments in Poland in the field of biogas and the use of solid biomass in former coal power plants[27], these projects are not expected to come online by 2020. Therefore, it can be expected that it will be difficult for Poland to fulfil its NREAP projections for bioelectricity.[28]

Based on France's NREAP projections, it appears that solid biomass for bioelectricity production is lagging, as it was projected to produce four times more bioelectricity than from biogas. Recent market developments show that one biomass power plant has come online in 2019, and a second is expected in 2022, but it is unsure if this will be sufficient to fill the gap towards NREAP projected bioelectricity production by 2020.[29]

[23] Data for total renewable and total generated power are based on Eurostat SHARES; data for solid biofuels, biogas, renewable MSW, bioliquids and total bioenergy are based on Eurostat nrg_bal_c.
[24] https://apps.fas.usda.gov/newgainapi/api/report/downloadreportbyfilename?filename=The%20Dutch%20Industrial%20Market%20for%20Biomass_The%20Hague_Netherlands_2-5-2019.pdf
[25] https://opendata.cbs.nl/statline/#/CBS/nl/dataset/84575NED/table?ts=1595416251791
[26] Poland National Renewable Energy Plan, Table 10a (2010).
[27] https://bioenergyinternational.com/heat-power/ze-pak-selects-valmet-to-convert-lignite-fired-boiler-to-biomass
[28] To note that both the Polish Progress Report comments on actions taken to reduce barriers for the production of renewable energy such as optimisation of support schemes.
[29] http://biomassmagazine.com/articles/15900/france-considers-biomass-conversion-of-cordemais-power-plant

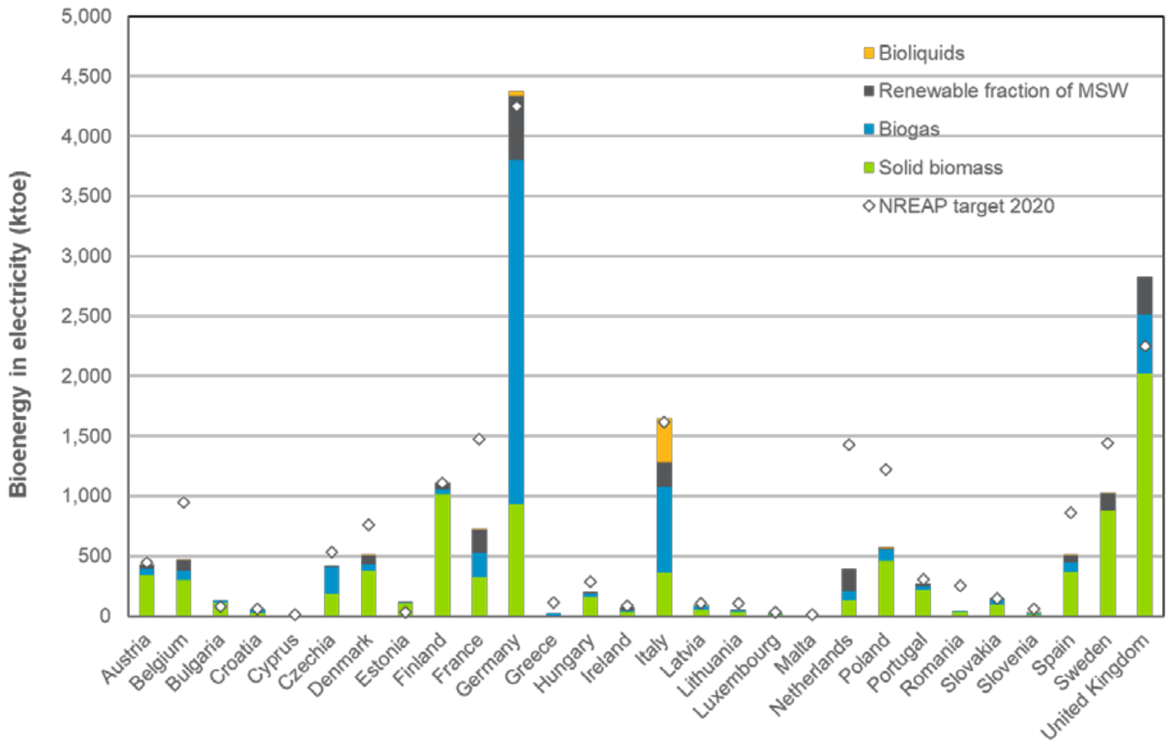

Figure 5. Bioenergy consumption for electricity versus NREAP[30] (2018, ktoe). Source: Eurostat nrg_bal_c, ECN[31]

As discussed in the previous section, most of the solid biomass consumed in the EU originates from the EU, with only approximately 10% being imported.[32] Solid biomass is traded within Europe and the market and details for feedstocks are discussed in Section 3.1. In the previous section, it was also explained that it is likely that all biogas feedstocks originate from the EU since it is uncommon to trade these types of feedstock over larger distances.

The third largest source for bioelectricity generation after solid biomass and biogas is the renewable fraction of Municipal Solid Waste (MSW). Overall, the EU has experienced an increasing trend in the use of MSW for bioelectricity generation (see Table 1). In 2018, Germany was by far the largest consumer of MSW for power generation, accounting for 27% of the EU consumption followed by the UK (16%), Italy (10%), France (10%), the Netherlands (9%) and Sweden (7%). Most of this feedstock is domestically produced, although some countries such as Sweden, Germany, and the Netherlands with overcapacity of waste-to-energy plants import waste from other EU Member States, primarily the UK which exported 3.13 million tonnes of solid recovered fuels (SRF) or refuse derived fuels (RDF).[33] The Netherlands, however, has imposed a tax on imported waste as of 1 January 2020 which is expected to increasingly diminish waste imports in the coming years.[34]

Bioliquids only have a small role in the generation of bioelectricity compared to solid biomass, biogas and MSW. Their deployment is almost limited to Italy and mainly concerns vegetable oils, including some imported palm oil.

Figure 6 shows the role of biomass in electricity consumption for each Member State in 2017 and 2018. Typically, the share of bioelectricity in total electricity production is above average in more northern located countries (Denmark, Finland, Estonia, Latvia, the UK, Germany and Sweden),

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[30] 2020 indicative NREAP sectoral targets for bioenergy in power.
[31] www.ecn.nl/nreap (update 2011).
[32] Note that the 10% is based on total imports. Net import would be 5%.
[33] https://www.letsrecycle.com/news/latest-news/rdf-exports-plateau-2017/
[34] https://www.euwid-recycling.com/news/policy/single/Artikel/netherlands-will-apply-hefty-tax-to-rdf-imports-as-of-2020.html

whereas several southern located countries sparsely use biomass in renewable electricity production (Malta, Greece, Cyprus, Romania). In some countries, this relates to the domestic resource base, such as the large forestry industry in countries such as Finland, Estonia, and Latvia and the extensive use of straw from the agricultural sector in Denmark. However, other factors, such as the deployment of combined heat and power or the phasing out of coal could trigger the use of biomass for electricity production. The UK does not have a large solid biomass resource basis, and as we will see in Section 3.1, mostly relies on imports in order to fuel the Drax and Lynmouth biomass power plants.[35] Bulgaria has seen a large increase between 2017 and 2018, mainly caused by a large increase in solid biomass use for electricity. As indicated in their Progress Report, this was due to the transition of existing plants from conventional fuels to solid biomass.

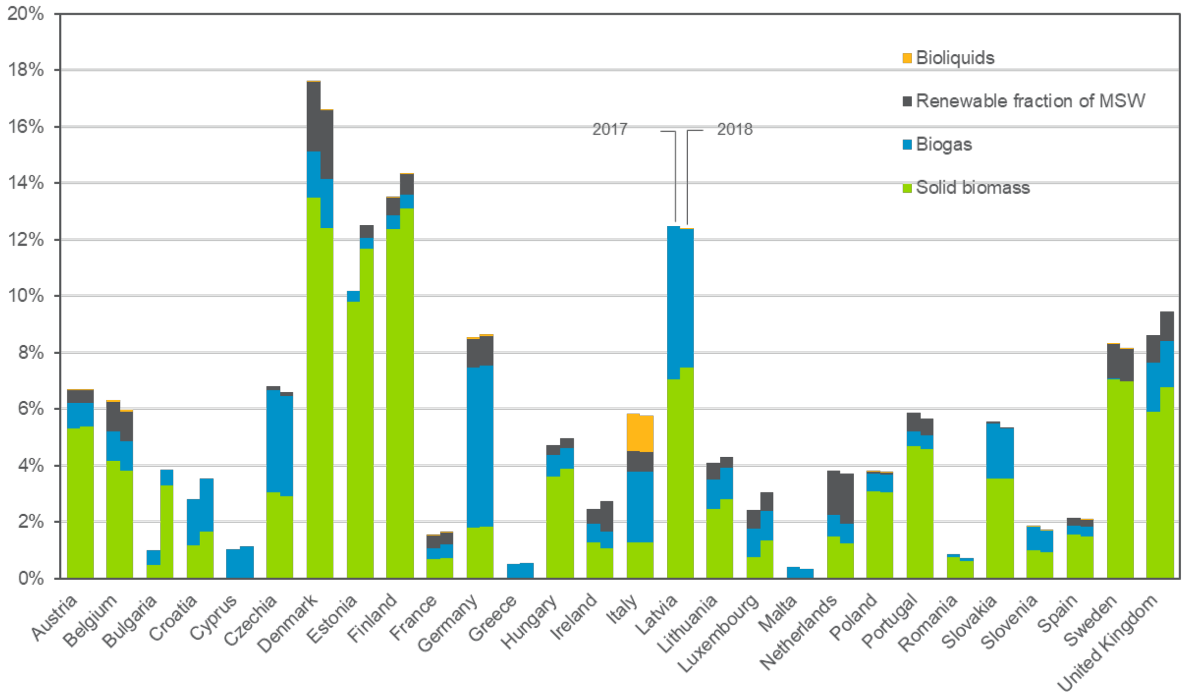

Figure 6. Bioelectricity share in total electricity production (2017-2018, %). Source: Eurostat nrg_bal_c and SHARES[36]

2.2.3 Bioenergy in Transport

Bioenergy in transport is discussed in Section 2.3, where the progress towards the 2020 10% target for all Member States for renewable energy in transport is assessed. This analysis takes into account the other forms of renewable energy and the multiple counting options as specified in the Renewable Energy Directive. Section 2.3 is mainly based on the Eurostat SHARES dataset as this was specifically developed for the renewable energy reporting in the framework of the Directive. In this section, the absolute amounts of bioenergy are discussed based on a different Eurostat dataset

[35] Bioenergy Europe Statistical Report – Pellet 2019 – European Pellet Council.
[36] Eurostat SHARES reports the production of electricity from solid biofuels, but it does not give information about the other subcategories. These other categories are reported by Eurostat nrg_bal_c. Note that Eurostat nrg_bal_c and SHARES report similar values for solid biofuels and for the total RES-E denominator, which suggests that nrg_bal_c is a reliable source for renewable energy in electricity generation. Bioliquids (the term used in the Renewable Energy Directive) is taken as the total of the categories “biodiesels” and “other liquid biofuels”. Solid biomass equals the category solid biofuels in nrg_bal_c.

(nrg_bal_c), which does not distinguish between the different sustainability categories, but does provide more insight into the material forms of bioenergy.[37]

Table 2 below shows the final bioenergy consumption in the EU transport sector in 2018. Over 99% of this bioenergy was consumed in road transport. There is a small use of biodiesel in rail transport (12 ktoe in Germany, 5 ktoe in Czechia) and a smaller use of biogasoline[38] and biodiesel in domestic navigation. Although the use of bioenergy in domestic aviation is reported to be zero, multiple airlines are trialling biojet fuels. IATA Environment estimates that 30 million litres of sustainable aviation fuel (SAF) was consumed globally in 2019. No details are available for the share of this consumption taking place in the EU.[39] The majority of this is biojet fuel and only a very small fraction is produced from non-biomass feedstocks such as industrial off-gasses. From 2020 onwards, Member States will be asked to separately report on biofuel consumption in aviation.

The majority (99%) of the bioenergy consumption in transport is from liquid biofuels, mainly biogasoline and biodiesel. A small amount of biogas is consumed in road transport in Sweden (118 ktoe), Germany (33 ktoe) and Norway (18 ktoe).

Table 2. Total final bioenergy consumption in EU transport sub-sectors (2018, ktoe). Source: [Eurostat nrg_bal_c][1)]

	Solid biofuels	Biogas	Bio gasoline	Biodiesel	Other liquid biofuels	Bio jet kerosene	Total Liquid biofuels	Total
Road	-	153.8	2,997.2	13,629.9	0.7	-	16,627.8	16,781.7
Rail	0.0	0.0	0.0	26.3	0.0	-	26.3	26.3
Domestic aviation	-	-	0.0	0.0	0.0	0.0	0.0	0.0
Domestic navigation[2)]	-	0.0	2.0	5.0	0.0	-	6.9	6.9
Non-specified transport	-	0.0	0.0	5.6	0.0	0.0	5.6	5.6
Total	**0.0**	**153.8**	**2,999.2**	**13,666.7**	**0.7**	**0.0**	**16,666.6**	**16,820.5**

1) Eurostat categories “charcoal” and “municipal solid waste” are excluded from the table, as they are not consumed in transport according to Eurostat nrg_bal_c. Eurostat category “consumption in pipeline transport” consumes no biofuels and has been excluded from the table. Total of liquid biofuels is the total of biogasoline, biodiesels, other liquid biofuels and bio jet kerosene. Unlikely combinations (e.g. solid biofuels in aviation) are indicated with “-”.
2) Domestic navigation includes all the quantities delivered to vessels of all flags within Europe as well as inland navigation and yachting.

Figure 7 shows the 2018 consumption of bioenergy in transport by Member State and fuel type compared to the 2020 NREAP targets. In absolute volumes, France and Germany are the largest consumers of bioenergy in transport, followed by Spain, Sweden, the UK and Italy.

For most Member States, 2018 volumes of bioenergy used in transport have not yet reached the level of the 2020 indicative targets set in their NREAPs. Some Member States like the UK, Spain, Italy and Poland are still far from their indicative 2020 NREAP targets, while others may reach their targets within the next few years. Sweden and especially Germany have surpassed the level of their original NREAP targets by far.

[37] Eurostat nrg_bal_c reports on the Supply, transformation and consumption of renewable energies. For transport it only reports contributions from biomass, and the results of other forms of renewable energy are reported to be zero. From the specific reporting on the share of renewable energy in transport in the SHARES Eurostat dataset it is clear that renewable electricity plays some role. However, this is not recognised in set nrg_bal_c.
[38] Eurostat nrg_bal_c reports amongst others on biogasoline. Eurostat definitions and glossary do not give insight into what exactly is included in biogasoline. Market insights make clear this must mainly concern bioethanol.
[39] Personal communication with IATA Environment, May 2020.

It should be noted that although Member States have set indicative sectoral trajectories for the introduction of bioethanol, biodiesel and other biofuels in their NREAPs, their policies for the reporting years were rather driven by the 10% overall target for renewable energy in transport, as well as the anticipation of de facto lower targets in the REDII, as is analysed in the next section.

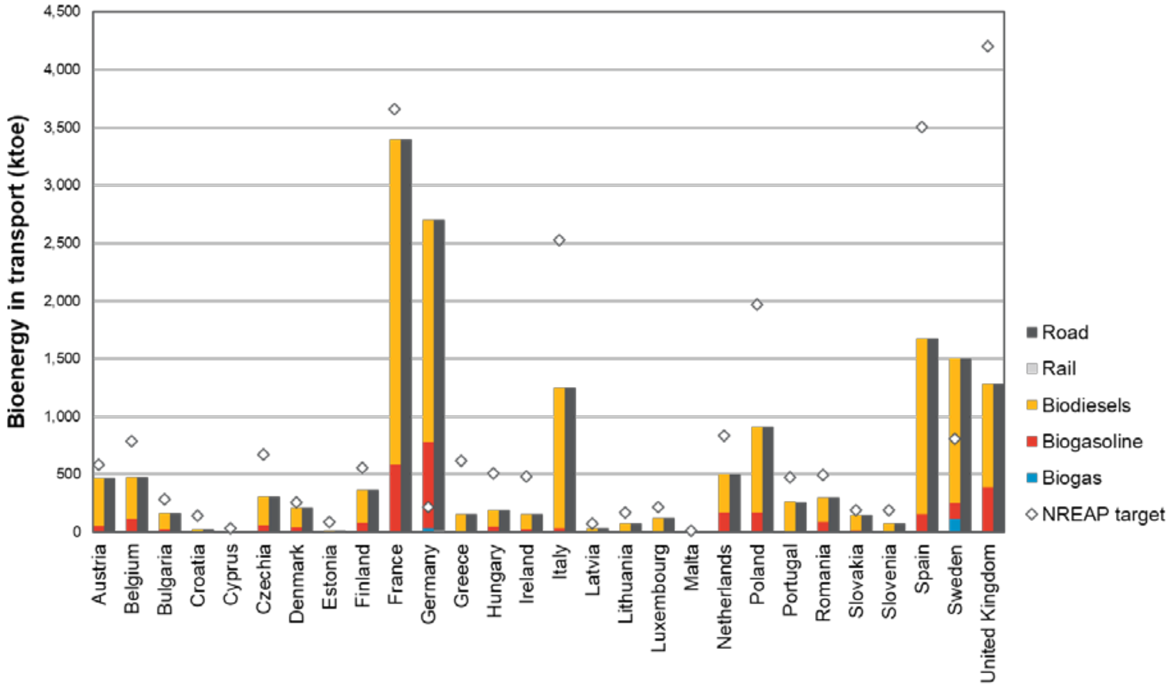

Figure 7. National consumption of bioenergy in transport in 2018 versus 2020 NREAP targets. Source: ECN[40], Eurostat nrg_bal_c

[40] www.ecn.nl/nreap (update 2011).

2.3 Progress towards the 2020 targets for renewable energy in transport

Renewable energy use in transport, known as RES-T, reached an 8.0%[41] share in 2018, having continuously increased since 2004 (apart from an accounting decline registered in 2011-2012[47]).

As shown in Table 3, biofuels[42] represent most of the renewable energy consumed in transport, largely in the form of biodiesel[43] (81%), followed by bioethanol (18%) - directly replacing fossil diesel and gasoline respectively. Gaseous biofuels represent only a minor share (1%).

Table 3. Share of renewable energy in transport (2018). Source: Eurostat SHARES[1)]

	Real deployment (ktoe)	Multiplication factor	Administrative contribution (ktoe)	Resulting RES-T share
Annex IX biofuels	3,905	2 x	7,810	2.5%
Other compliant biofuels[2)]	12,692	1 x	12,692	4.1%
Non-compliant biofuels	88		0	0.0%
Renewable electricity in road transport	52	5 x	260	0.1%
Renewable electricity in rail transport	1,618	2.5 x	4,045	1.3%
Renewable electricity in other transport modes	291	1 x	291	0.1%
Other renewable energy	0.04	1 x	0.04	0.0%
Total RES-T numerator			**25,098**	8.0%
Total RES-T denominator			312,706	

1) Numbers for real deployment and administrative contribution (after applying multiplication factors) towards the 2020 sum of 10% Member States target of the Renewable Energy Directive.
2) "Other compliant biofuels" includes biofuels that fulfil the sustainability criteria but that are not categorized as "Annex IX" by the ILUC Directive.

The share of renewable energy in transport has grown from 6.9% in 2016 to 8.0% in 2018. To meet the 2020 sum of Member States targets of 10% renewable energy in transport, the share needs to increase at a rate of 12% in the coming years, which is higher than the growth rate of 8% over the past two years.

In the Renewable Energy Directive, the concept of double counting biofuels was introduced. Initially this concerned "wastes, residues, non-food cellulosic material, and ligno-cellulosic material" while the 2015 ILUC Directive introduced a list of specific feedstocks in what became Annex IX of the Renewable Energy Directive. Most Member States have by now adopted legislation to increase the market value of double counting biofuels,[44] and this has triggered a strong increase in the sales of these fuels, in particular for biodiesel from used cooking oil, tall oil, and waste-based biogas (see Section 4.3). The share of these fuels has again grown in the period 2016-2018 and now represents 2.5% of the RES-T, after double counting.

Today, these Annex IX biofuels account for over one third of the biofuel share (after double counting). The "other compliant biofuels" concern biofuels that fulfil the sustainability criteria, but that are not categorised as "Annex IX". It includes biofuels from a range of feedstocks according to Article 3(4)d and e of the ILUC Directive.[45]

[41] Following the accounting method of the 2009 Renewable Energy Directive, the share of renewable energy in transport is established by dividing the total amount of renewable energy in transport (numerator) by the total amount of all energy in transport (denominator). The numerator concerns all types of energy from renewable sources consumed in all forms of transport. The denominator concerns only petrol, diesel and biofuels consumed in road and rail transport, plus electricity in all transport. This means the scope of the numerator and denominator is slightly different. Furthermore, a multiplicator is applied to some forms of renewable energy: biofuels produced from waste feedstocks count double, electricity in rail counts 2.5 times, and electricity in road transport counts 5 times.
[42] Note that biofuels for transport, as defined in the Renewable Energy Directive, also includes biogas.
[43] Note that hydrotreated vegetable oil (HVO) and hydrotreated crude tall oil (HCTO) are included in the biodiesel category.
[44] It is necessary to distinguish between the double counting rule in the Renewable Energy Directive and support measures in national legislation. The former implies that Member States *may* double count the contribution of these fuels towards the national targets (and in their bi-annual reporting to the EC). Member States can translate this double counting possibility to incentives, for instance by allowing economic operators to double count Annex IX fuels towards their blending mandates. Note that Member States do not have to support this type of fuels, as long as the national targets are met.
[45] Article 3(4)d: […] "*biofuels produced from cereal and other starch-rich crops, sugars and oil crops and from crops grown as main crops primarily for energy purposes on agricultural land" […].* Article 3(4)e: […] " *biofuels made from feedstocks not listed in Annex IX that were determined to be wastes, residues, non-food cellulosic material or ligno-cellulosic material by the competent national authorities*" […].

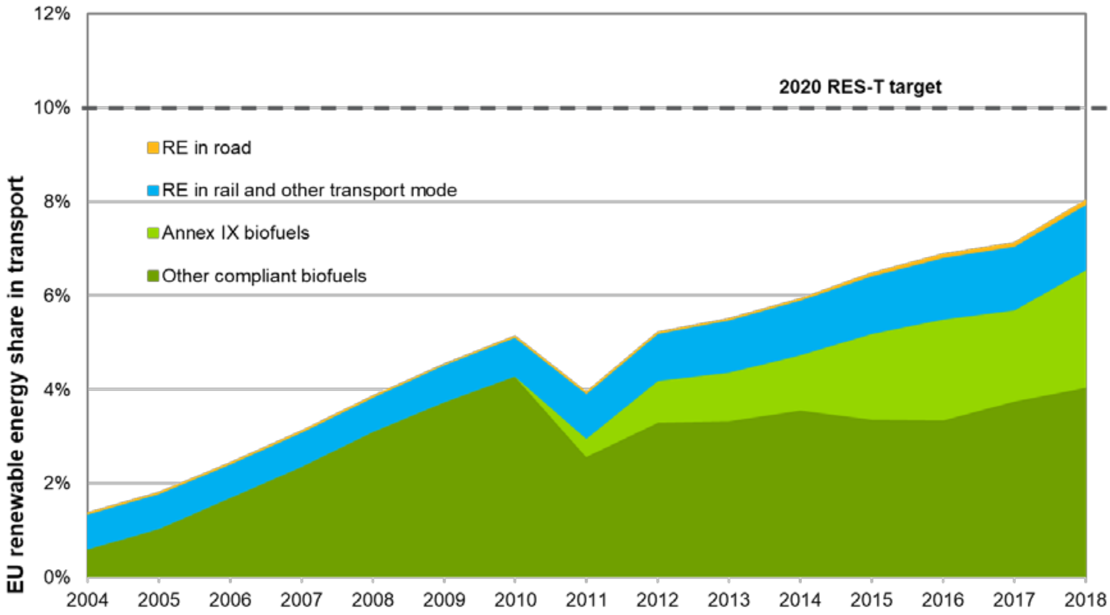

Figure 8. Historical overview of renewable energy in EU transport.[46] Source: Eurostat SHARES[47]

The contribution of renewable electricity in rail (and other transport modes) has been growing slowly, mainly due to an increasing share of renewable electricity. In Figure 8, the contribution is considerable, but note that electricity in rail is counted 2.5 times. Renewable electricity in road transport is negligible, but slowly increasing (further discussed below).

After years of strong growth between 2005 and 2010 (0.6 percentage point per year on average), since 2012 the share of renewable energy in transport grew at a slower pace (0.4 percentage point annually on average), with a higher growth in 2018. In the former period, the development was mainly driven by attractive tax support policies. In the latter period, the development slowed down, mainly because national blending mandates were set just above what was already achieved. In the largest market, Germany, the support instrument changed from a blending mandate to a CO_2 emission reduction mandate, which de facto led to the use of biofuels with higher greenhouse gas savings, while requiring less volumes to achieve the same savings.[48]

In 2015, the ILUC Directive came into force, amending the Renewable Energy Directive and introducing a 7% cap on the share of food and feed crop-based biofuels and a non-binding national target for advanced biofuels of 0.5% by 2020 (sources from feedstock lister in Annex IX, part A[49]). In some Member States, this 7% limit was already almost reached in 2016 (Bulgaria, France, Austria

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[46] Numbers after application of multipliers for renewable electricity and Annex IX biofuels in line with the ILUC Directive.
[47] Note that data for Annex IX biofuels is only available from 2010 onwards. The dip in 2011 (and to a lesser extend 2012) is mainly caused by the change in reporting requirements. Until 2010, all biofuels were counted towards the RES and RES-T shares. From 2011 onwards, Member States are only allowed to report biofuels and bioliquids that are compliant with the sustainability criteria set out in Article 17 and 18 of the Directive 2009/28/EC. Many Member States (Bulgaria, the Czechia, Estonia, Spain, France, Croatia, Cyprus, Finland, Portugal and Romania) were late in their late transposition and implementation of Directive 2009/28/EC and therefore not able to verify or administrate the compliance of the biofuels in their markets with the sustainability requirements. As a result, they could only report non-compliant biofuels which are not shown in the graph.
[48] The total volume of compliant biofuels in Germany decreased from 2,939 ktoe in 2012 to 2,548 ktoe in 2016, and this is not compensated by the increase in Annex IX double counting biofuels (from 412 ktoe to 623 ktoe) [Eurostat SHARES]. From 2014 to 2016, the average greenhouse gas emission per unit of biofuels has decreased from 41 g/MJ to 19 g/MJ. This is not only caused by the partial switch to waste based biofuels. For instance, in 2016, 82% of all corn ethanol sold in the German market achieved >65% emission reduction in comparison to the old fossil comparator of 83,8 g CO_{2eq}/MJ. Even 95% of all rapeseed biodiesel sold in the German market achieved >65% emission reduction [BLE 2016, Evaluations und Erfahrungsbericht für das Jahr 2015, Biomassestrom-Nachhaltigkeitsverordnung & Biokraftstoff-Nachhaltigkeitsverordnung, Bundesanstalt für Landwirtschaft und Ernährung, Bonn Germany]. In 2018, the total volume of compliant biofuels increased to 2686 ktoe, of which the Annex IX biofuels have increased to 792 ktoe [Eurostat SHARES].
[49] The term "advanced biofuels" is often used to indicate types of biofuels that are either produced via technologically more advanced production pathways (compared to traditional fermentation of sugars or starch, or to the (trans) esterification of vegetable oils), or that are produced from non-food crop biomass. The definition is ambiguous and often disputed. In the frame of the current report, we use "advanced biofuels" to indicate biofuels made from feedstock as listed in Annex IX A of the ILUC Directive EU 2015/1513.

and Slovakia) and these countries did not further raise their demand for these crop-based biofuels above the 7%. Please note that in the REDII, additionally a cap on Annex IX B biofuels was added, but it is not valid for this 2020 reporting period.

Support measures for Annex IX A biofuels still largely need to be developed. The supply of Annex IX A biofuels still comes from a limited number of producers. One of the reasons for this is that it is technically more difficult and consequently costly to develop new production capacity. The progress of these Annex IX A biofuels is discussed in Section 4.3.

Used cooking oil (UCO) is one of the feedstocks included in the double counting list of Annex IX (specifically in the capped amount of Annex IX B feedstocks). There has been concern that the attractiveness of double counting biofuels would stimulate the production of waste oils beyond their autonomous potential. The EC identified a risk of fraud[50] in situations where the value of double counting biofuels would become very high, and the value of used cooking oil could become higher than that of fresh vegetable oil. This could drive operators to fraudulently relabel fresh oil to used cooking oil without cooking it. There is also a risk of fraud further down the supply chain as the material price increases and larger volumes are traded. This includes, for example, selling non-sustainable material as sustainable or the relabelling of material.

In addition, used cooking oils are not always considered to be a waste material in all the countries where it is sourced from. For instance, in the USA, UCO is used in animal feed, and its use in EU biofuels could lead to fresh vegetable oil replacing this UCO. To address these concerns on stretching the demand for UCO, the REDII limits the contribution of fuels from Annex IX B feedstocks to a maximum of 1.7%.[51] The global potential for waste oils is sufficient to provide feedstock for EU biofuels up to this limit. Within Europe, the potential from restaurants is around 800 ktonne per year, of which over 80% is already collected. Germany, the UK, Spain and Italy are key markets, collectively representing over 50% of the potential. Currently, the potential of UCO from European households is estimated to be around 850 ktonne per year, however only about 6% (less than 50 ktonne) of this is currently being collected.[52]

The feedstocks for biofuels and their geographical origin are discussed in more detail in Section 4.4.

Figure 9 gives more detail on the application of renewable energy in transport in the Member States. It shows that some countries have already achieved the level of their RES-T targets and the RES-T increased in most Member States from 2017 to 2018, but that many Member States still have a large gap to fill to reach the 2020 target.

- **In 2018, Sweden and Finland already achieved the level of their 2020 RES-T target** by achieving shares of 30% and 15% of renewable energy in transport, respectively. In Finland, most of the RES-T was from Annex IX biofuels (double counted biofuels, including the multiplicators) and in Sweden it stemmed mainly from use of other compliant biofuels (single counted biofuels).
  - **After a strong dip in 2016, Finland recovered to target level in 2017 and 2018.** The dip in 2016 was probably caused by a new law that caps the options for transferring surpluses (administratively) to the following years (making it less attractive to surpass the mandated volumes). In 2016, the government announced to increase the share of biofuels in road transport fuels to 30% by 2030.[53] Also, the Act on promoting the use of biofuels for transport in Finland sets an obligation of 20% in 2020. The 2017 and 2018 values (respectively 19% and 15%) show a recovery and achievement above target, although they still demonstrate fluctuations.

[50] The European Commission letter, on the 10th October 2014, to Voluntary Schemes have been recognised by the Commission for demonstrating compliance with the sustainability criteria for biofuels https://ec.europa.eu/energy/sites/ener/files/documents/2014_letter_wastes_residues.pdf
[51] Member States can individually modify this limit, subject to the approval of the Commission.
[52] Analysis of the current development of household UCO collection systems in the EU, Greenea, 2016.
[53] Reuters, 2016 November 24, Finnish government lifts biofuel targets.

- Finland is also the country with the largest share of Annex IX biofuels, which mainly include HVO biodiesel produced from waste oils and residues.[54]
- **Since 2016, Sweden remained relatively stable at 30% of RES-T.** The major part comes from the use of other compliant biofuels (18%) and Annex IX biofuels (7%). The use of renewable electricity in trains contributes 5% (all numbers administratively, i.e. after the multiple counting).

- **From 2017 to 2018, RES-T increased in most Member States**, which is mainly caused by an increase in the use of Annex IX type biofuels that are double counted and other compliant biofuels (single counted biofuels).
  - The Netherlands showed a significant increase in RES-T. This was driven by an increase in the use of double counting Annex IX biofuels. According to the Dutch Progress Report, this was primarily caused by a 'sharpening' of national regulation on renewables in transport.

- **However, many Member States still have a large gap to fill to reach to 2020 target.**
  - Despite an increase from 2017 to 2018, the UK has the largest gap in absolute terms to reach the 2020 target. The target still has the potential to be met due to the updates made to the Renewable Transport Fuel Obligation (RTFO) Order in 2018, which significantly increased the target levels for fuel suppliers. The biofuel volume target was more than doubled from 4.75% biofuels in transport fuels to 9.75% in 2020. The increase of this mandate is expected to increase biofuel consumption in the UK to 2020 and onwards.[55]
  - Spain also has a considerable gap to fill in the coming years despite an increase from 2017 to 2018. Spain similarly has increasing biofuel mandates, and biofuel shares in transport fuels will increase from 6% in 2018 to 8.5% in 2020 and subsequently increase consumption. In addition, waste-based biofuels (Annex IX) began to be double counted as of January 1, 2019 which will stimulate the consumption of these fuels.[56] These two factors have the potential for Spain to reach the 10% target in 2020.
  - Italy also remains far from the 2020 target in absolute terms, but also has an increasing national biofuel target. The share of biofuels in transport fuels mandate will increase from 7% in 2018 to 9% in 2020, with a sub target for advanced biofuels from 0.1 to 1.0% (double counted).[57] Additionally, both Annex IX and other compliant biofuels production will increase with the opening of a new biorefinery producing HVO (600-700 ktonne annually) from both palm oil and UCO.[58] If this output is used domestically rather than exported, there is potential for meeting the target.

[54] UPM produces HVO from crude tall oil, which is listed in Annex IX A. The HVO verification scheme (www.hvoscheme.com/certificates/) shows that the Porvoo facility produces HVO based on amongst others animal fat cat 1, 2 and 3, UCO, and PFAD. Note that PFAD is not recognized as a waste feedstock by the ILUC Directive, but Finland grandfathered its application as a waste feedstock, which is allowed by the ILUC Directive.
[55] https://www.gov.uk/government/news/new-regulations-to-double-the-use-of-sustainable-renewable-fuels-by-2020
[56] USDA, Biofuel Mandates in the EU by Member State in 2019.
[57] USDA, Biofuel Mandates in the EU by Member State in 2019.
[58] https://www.ofimagazine.com/news/eni-gela-biorefinery-due-to-start-commercial-operations

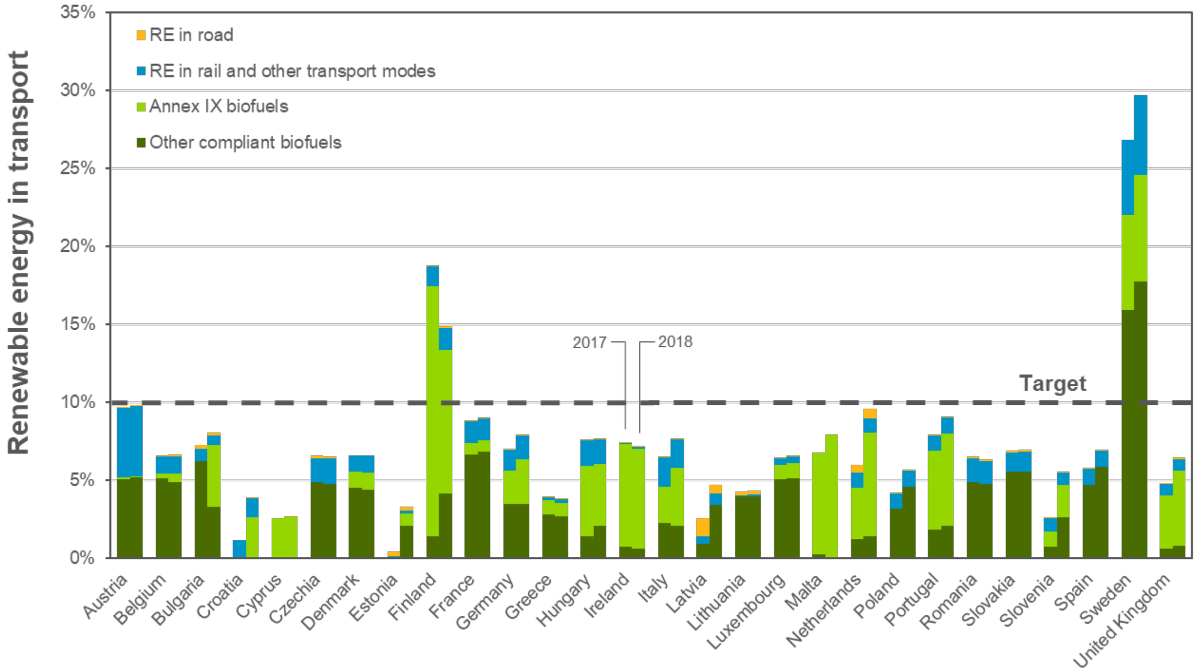

Figure 9. National share of renewable energy in transport (2017-2018).[59] Source: Eurostat SHARES

The contribution of renewable electricity in transport mainly concerns electricity in rail transport (1,618 ktoe) and other non-road transport (291 ktoe). Only a few countries show significant amounts of renewable electricity for road transport, most notably Latvia. This mainly includes the use of electricity in trams and trolleybuses.

The use of renewable electricity in passenger cars is small. This is mainly because the share of electric passenger vehicles in the total fleet is still small. The sales (new registration) of electric passenger cars[60] in the EU has grown sharply from 50,000 in 2013 to 217,000 in 2017 and 461,000 in 2019.[61] But even if all new vehicles would be electric, it would take decades to replace all the existing vehicles, and the electricity that the vehicles use is only partially renewable.

Biogas and biomethane derived from biogas accounts for only a small fraction (<1%, or 154 ktoe) of the total bioenergy used in transport. In fact, there are only a few Member States including Sweden, Germany, Finland, Denmark and Austria using biogas in transport. Sweden and Germany together account for over 98% (77% Sweden and 22% Germany) of the total EU biogas consumption in transport.[62]

Hydrogen falls in the category of “other renewable energies”, which contribute less than 0.001%, as shown in Table 3. Table 4 provides a detailed historical overview of biofuels and other renewable energies used in transport in the EU.

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[59] Categories and accounting are according to the methodology set out in Directive 2015/1513.
[60] pure electric and plug-in hybrids.
[61] European Alternative Fuels Observatory, eafo: http://www.eafo.eu/
[62] Eurostat database, nrg_bal_c.

Table 4. Renewable energy consumption in all transport in the EU28 (2011-2018, ktoe).[63] Source: Eurostat SHARES

Product/time	2011	2012	2013	2014	2015	2016	2017	2018
Renewable electricity in road	11	11	15	18	24	33	42	52
Renewable electricity in rail	1,077	1,101	1,205	1,268	1,368	1,501	1,575	1,618
Renewable electricity in other modes	201	198	216	231	267	281	288	291
Compliant biofuels	8,424	11,037	11,183	12,238	12,830	13,575	14,758	16,597
Annex IX	584	1,289	1,506	1,726	2,739	3,277	3,017	3,905
Other compliant biofuels[1)]	7,840	9,748	9,678	10,512	10,092	10,298	11,741	12,692
Non-compliant biofuels[2)]	5,326	3,358	1,901	1,953	1,129	182	109	88
Other renewable energies	0.0	0.0	0.3	0.3	0.1	0.2	0.1	0.0
Total renewable energy in transport (including multipliers)	11,956	15,332	15,992	17,457	19,327	21,049	22,212	25,098
Total fuels used in transport[3)]	**302,974**	**293,932**	**290,269**	**294,245**	**299,551**	**306,174**	**311,635**	**312,706**
RES-T Share (%)	**3.9%**	**5.2%**	**5.5%**	**5.9%**	**6.5%**	**6.9%**	**7.1%**	**8.0%**

1) Other compliant biofuels and biofuels include in the first and third paragraphs of article 3(4)d of the Directive 2015/1513
2) "Non-compliant" biofuels are biofuels that do not meet criteria of sustainability (Articles 17 and 18 of the Renewable Energy Directive). This means that they can be either non-sustainable or that they cannot be certified as sustainable. The latter especially occurred in 2011 and 2012 when the certification scheme was not operational in some Member States.
3) Total electricity, diesel, gasoline and biofuels used in the transport; biofuels included with multiplicators.

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63 All calculations follow the rules set out in the ILUC Directive.

3. Bioenergy supply

The use of bioenergy in heating and cooling, in power production and in transport was discussed in Chapter 2. This chapter provides additional detail on bioenergy supply, including bioenergy carriers and their origin. Bioenergy can be produced from many types of agriculture, forest and waste feedstock, that can be categorised in material forms in different ways. The categorisations used by Eurostat of solid biomass, biogas, bioliquids, biofuels and the renewable fraction of municipal solid waste provide more insight into the nature of the feedstock.[64]

Solid biomass is the main form of biomass for energy in the EU, as it represents 95% of the bioenergy in heating (which in turn represents 72% of all primary bioenergy), and 53% of bioenergy in electricity generation (14% of all primary bioenergy). Most of this solid biomass (90%) originates from the EU and mainly consists of forestry and forest industry products and residues (74%). The USA, Canada and Russia are together responsible for supplying 89% of the EU import of wood pellets. The UK is the largest importer of wood pellets, mainly from the USA and Canada.

Biogas is the second largest form of bioenergy in the EU representing a 12% share of all primary bioenergy, or 16.8 Mtoe. It produces 5.2 Mtoe of power and 3.9 Mtoe of heat. Germany is by far the largest producer and consumer of biogas. Most of the biogas is produced from crops, agricultural residues, manure and food-industry residues. Furthermore, the UK has significant biogas production from landfills, with also a large share in France. Most, if not all, the feedstock for biogas consumed in the EU originates from the EU, and often from the same country as it is consumed.

Bioliquids represent only 3% of bioelectricity and less than 1% of total bioenergy consumption. It is mainly consumed in Italy, where it consists of palm and rapeseed oil, UCO and animal fat.

The contribution of the renewable fraction of municipal solid waste (MSW) to the total gross bioenergy consumption was 7% in 2018. All this MSW originates from the EU, but some is traded between Member States.

3.1 Solid biomass

3.1.1 Consumption of solid biomass for energy in the EU

Almost all bioenergy consumed in heating and cooling in the EU in 2018 was based on solid biomass (95% of the total, equivalent to 80.1 Mtoe) as indicated in Figure 2. The major EU consumers of solid biomass for heat production were France (9,792 ktoe), Germany (9,623 ktoe), Sweden (7,584 ktoe), Italy (7,264 ktoe) and Finland (7,115 ktoe). These countries accounted for more than 50% of the total solid biomass consumed in 2018 (see Figure 4).

Also, more than half of the bioelectricity is produced from solid biomass (again, see Figure 2). By far the largest consumer of solid biomass for power production was the UK (2,023 ktoe), representing 24% of the EU total, followed by Finland (1,016 ktoe), Germany (931 ktoe) and Sweden (877 ktoe).

The total consumption of solid biomass in both heat and power production in the EU in 2016 is estimated to be 88.6 Mtoe on the basis of a combination of Eurostat and Member State Progress Reports (see Section 2.2 and specifically Figure 2). Note that this is less than the total reported consumption of “solid biofuels” of 99.4 Mtoe, reported by Eurostat, as both shown in Table 6 later in this section. This discrepancy cannot be explained from the available data.

[64] These categories are used in Eurostat in several datasets used in the current study.

Solid biomass can include wood directly supplied from forests and other wooded land, residues and co-products from the forest-based industry (e.g. wood processing or pulp and paper industry), energy crops and short rotation trees, and agricultural and food industry wastes and by-products. For major EU consumers of solid biomass (Germany, Sweden, Italy and Finland[65]), the nature of the solid biomass used for heat and power generation is given in Table 5.[66] In Sweden and Finland, residues and by-products from wood industry was the main source of solid biomass for heat and power generation, while in Italy and Germany, forest biomass from forest and other wooded lands was the main source.

For instance, in Finland, a country with a large forest industry, bioelectricity is mainly sourced from wood products: about 30% comes directly from the forest and 70% concerns residues from forest-based industry. Also, in Sweden, by far the majority of bioelectricity comes from wood products: 21% directly from the forest and 77% from forest-based industry. The remainder comes from agricultural by-products, processing residues and fishery by-products. In Germany, 60% of the solid biomass concerns wood products from forests and 30% concerns wood processing (industry) residues, while agricultural by-products are mainly used for biogas production (Section 3.2).

Table 5. Solid biomass supply for heat & electricity in major EU consumers (2018, ktoe). Source: MS Progress Reports

	Germany		Sweden		Italy		Finland	
Feedstock	Domestic	Import	Domestic	Import	Domestic	Import	Domestic	Import
Wood biomass from forest and other wooded lands for energy generation	5,947	256	2,020	9	5,468	379	2,718	1
Wood biomass residues and by-products from wood industry	2,590	470	6,532	783	543	1,064	6,232	66
Energy crops and short rotation trees	-	0	13	0	1,336	596	-	0
Agricultural by-products/processed residues and fishery by-products	1,013	0	60	60	1,126	0	-	0
Total	**9,550**	**726**	**8,625**	**852**	**8,473**	**2,039**	**8,950**	**66**

The table also shows that these Member States mainly relied on the supply of domestic raw materials with imports accounting for less than 20% of their total consumption. Italy imported 19% of their total consumption (fraction of import in sum of import and domestic supply), Germany, Finland and Sweden imported less than 10% of their consumption. International trade is discussed later in this section.

3.1.2 Production of solid biomass for energy in the EU

Figure 10 shows how the solid biomass production for energy purposes in the EU gradually increased between 2014 and 2017 with a compound annual growth rate of 2.4% and stabilized over the period 2017-2018. This trend is mainly driven by the increasing demand for both renewable heat and renewable electricity in the EU, as was discussed in Section 2.2. The link between the demand for and the production of solid biomass for energy becomes especially clear from the overview given in Table 6.

Germany is the largest EU producer of solid biomass for energy in 2018, followed by France, Sweden and Finland.

[65] The French Member State Progress Report did not cover the supply of solid biomass.
[66] Data are from Member State's reports. Note that Member States did not split the solid biomass consumption between the electricity and heat sectors.

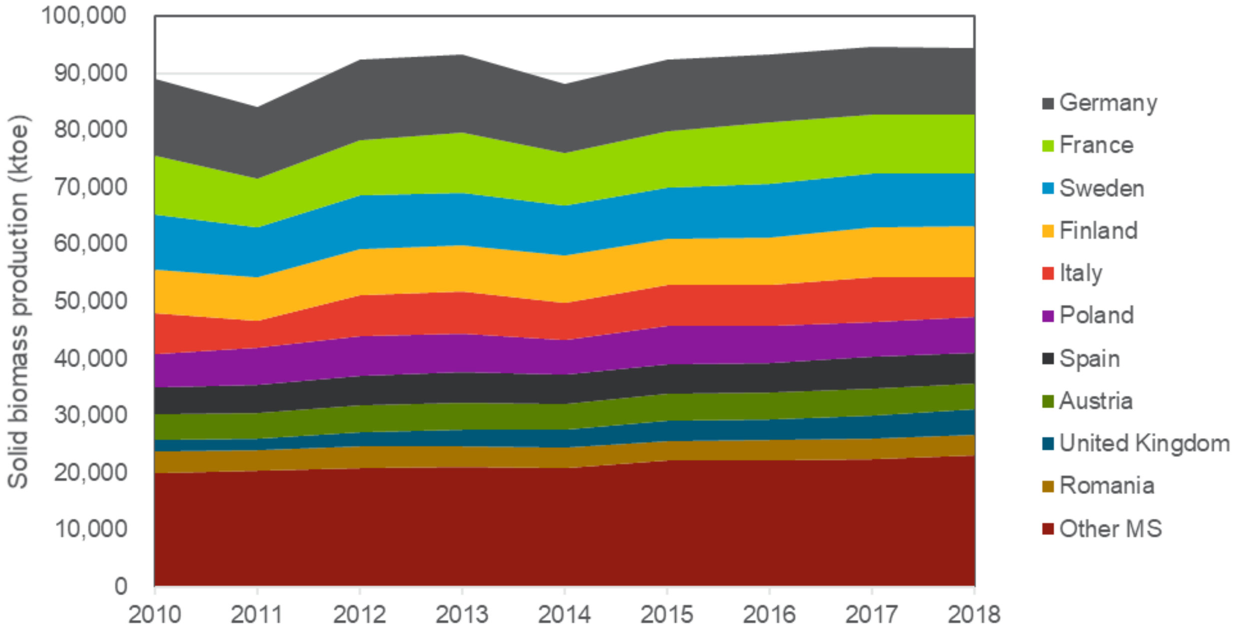

Figure 10. Solid biomass primary production (2010 – 2018)[67]. Source: Eurostat nrg_bal_c

Table 6 shows solid biomass production, import, export and consumption in the EU between 2010 and 2018. The major feedstocks for solid biomass have been forms of wood (~77%, including fuelwood[68], wood residues and by-products as well as wood pellets) followed by black liquor (~14%)[69].

Table 6. Solid biomass production, import, export and consumption in the EU (ktoe). Source: Eurostat nrg_bal_c

	2010	2011	2012	2013	2014	2015	2016	2017	2018
Total EU solid biomass production	88,989	84,148	92,314	93,362	88,122	92,253	93,144	94,659	94,353
Total import of solid biomass	5,771	6,099	6,239	7,682	9,014	8,854	9,259	9,400	10,245
Total market (EU production + import)	94,760	90,247	98,554	101,044	97,136	101,107	102,403	104,059	104,599
Total export of solid biomass	2,699	3,176	3,644	4,041	4,446	4,698	4,672	4,653	4,926
Change in stock	107	-186	-77	126	-67	-52	9	161	-228
Total consumption of solid biomass	**92,168**	**86,885**	**94,833**	**97,129**	**92,623**	**96,357**	**97,740**	**99,567**	**99,444**

The import of solid biomass, as total market share, has slowly increased from 6.1% in 2010 to 9.8%[70] in 2018 as can be seen from Table 6. The origin of imported solid biomass is further discussed later in this section. The total market (EU production + import) has been growing with a compound annual growth rate of 1.9% over the period 2014-2018, but growth from 2017 to 2019 was only 0.5%. The majority of solid biomass is used in the heating & cooling sector, where the bioenergy consumption needs to grow by 3.2% in the coming years to reach the 2020 NREAP target, as described in section 2.2.1.

[67] Data are shown for the 10 Member States with the largest production volume in 2018; The other Member States are aggregated. Data on 'primary solid biofuels'. Note that Eurostat does not give statistics on "solid biomass", but rather on "primary solid biofuels". We presume these terms effectively cover the same material scope.
[68] Definition of fuelwood (also known as wood fuel) by the European Commission: "*Roundwood being used as fuel for purposes such as cooking, heating or power production. It includes wood harvested from main stems, branches and other parts of trees (where these are harvested for fuel) and wood that is used for the production of charcoal (e.g. in pit kilns and portable ovens), wood pellets and other agglomerates. It also includes wood chips to be used for fuel that are made directly (i.e. in the forest) from roundwood. It excludes wood charcoal, pellets and other agglomerates*." It can be accessed via the link: https://ec.europa.eu/knowledge4policy/glossary/wood-fuel_en
[69] Eurostat categorises black liquor as a solid biofuel, while it is technically a viscous liquid.
[70] Note that the 9.8% is based on total imports. Net import would be 5%. In the same year the EU export of solid biomass was about 5 Mtoe (Eurostat nrg_bal_c). Please note that the export is not necessary a proportion of the domestic production. All or part of the export can be from imported solid biomass.

Figure 11 shows the primary solid biomass supply by Member State. German solid biomass production amounted to 12,608 ktoe in 2018, 91% of which was from forest biomass[71] (fuelwood, wood residues and other by-products as well as wood pellets). The increasing demand for solid biomass in France is primarily attributed to increasing demand for collective residential heat and industrial power.[72] Similar to Germany, the majority (89%) of solid biomass in France concerns wood-based products (Figure 11). In Sweden and Finland, a significant amount of solid biomass (43% and 44% respectively, Figure 11) is sourced from domestically produced black liquor – a by-product of the Kraft wood pulping process.[73] These two countries are the largest producers of black liquor in the EU and together account for about ~60% of the EU production,[74] followed by Portugal,[75] Austria, France, Spain and Germany. In Italy, all solid biomass is sourced from fuelwood, wood residues and by-products according to Eurostat nrg_cb_rw. However, in its Member State Progress Report, Italy reports 18% of energy crops and short rotation trees and 11% of agricultural by-products, processed residues and fishery by-products, next to a majority of 71% of wood biomass (Table 5).

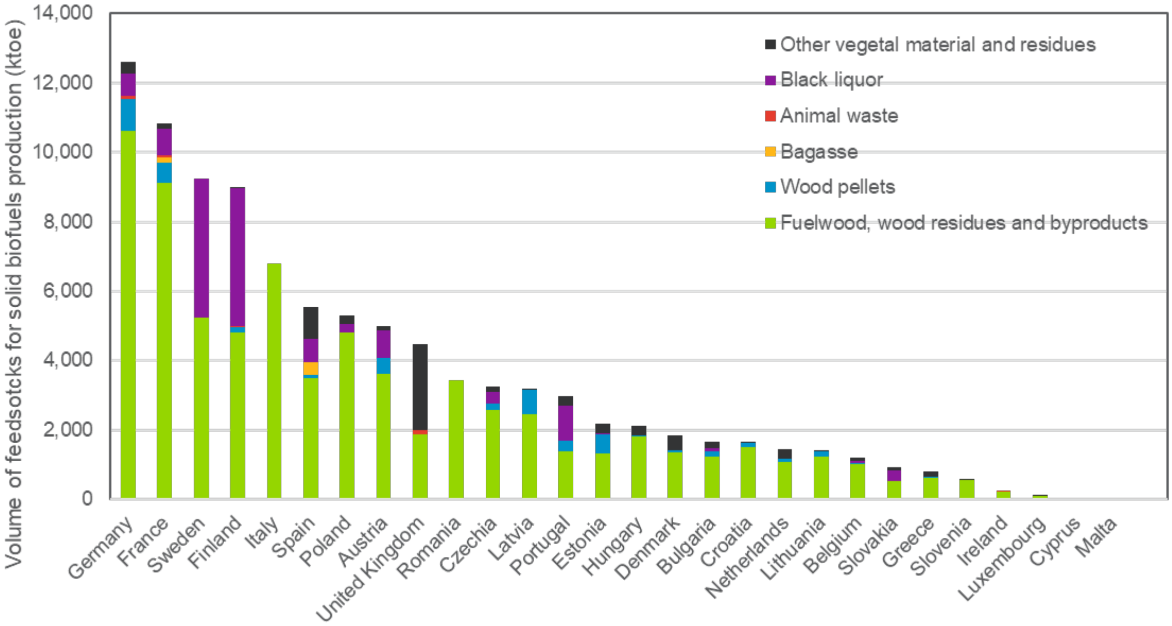

Figure 11. National primary solid biomass supply (2018, ktoe). Source: Eurostat nrg_cb_rw data on 'solid biofuels'[76]

3.1.2.1 Origin of solid biomass

As discussed above, most of the solid biomass consumed for energy production in the EU originates from the EU. The import of solid biomass represented only about 10% (10 Mtoe) of the total consumption in 2018.[77] A trade analysis approach, described below, based on Eurostat International Trade statistics[78] is used to identify the origin of the imported solid biomass.

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[71] Note that the term "forest biomass" is used in the recast of the Renewable Energy Directive, and in the frame of that Directive such biomass shall meet certain additional sustainability criteria. Eurostat does not specifically cover "forest biomass". Some material forms reported by Eurostat are assumed to fall in the "forest biomass" category, as further explained under Table 6.
[72] Pellet market country report France, ADEME: https://pelletsatlas.info/wp-content/uploads/2015/09/France_CR.pdf
[73] Eurostat includes "black liquor" in its definition of "solid biofuels". Technically, black liquor is a liquid, albeit very viscous.
[74] Eurostat database, energy statistics, nrg_cb_rw.
[75] http://ec.europa.eu/DocsRoom/documents/10271/attachments/10/translations/en/renditions/pdf
[76] Note that Eurostat does not give statistics on "solid biomass", but rather on "primary solid biofuels". We presume these terms effectively cover the same material scope.
[77] Note that the 10% is based on total imports. Net import would be 5%. In the same year the EU export of solid biomass was about 5 Mtoe (Eurostat nrg_bal_c). Please note that the export is not necessary a proportion of the domestic production. All, or part of, the export can be from imported solid biomass.
[78] Figures were obtained from Eurostat, Database by Themes, International Trades, International Trades in goods - detailed data, the dataset "EU trade since 1988 by HS 2, 4, 6 and CN8" and can be found at https://ec.europa.eu/eurostat/data/database

In the following section we provide additional detail on imports of wood pellets and wood chips to the EU28. On the types of solid biomass listed in Table 6, Eurostat provides international trade data for wood pellets and wood chips (as part of the 'fuelwood, wood residues and by-products' category) in disaggregated forms. Disaggregated trade data for bagasse, black liquor, other vegetal materials and residues and animal waste are not included in the Eurostat International Trade statistics.

Wood pellets import

Wood pellets accounted for 5% of solid biomass production in the EU in 2018, as shown in Figure 11 in the previous section. Imports made up 50% of the total wood pellet market in the EU. Wood pellets make up 46% of the total solid biomass import.[79]

Figure 12 shows the EU wood pellets imports between 2016 and 2018. The EU imported 10,355 ktonne of wood pellets for energy use in 2018[80]. This represents an increase of almost 28% compared to 2016. Figure 12 also shows the EU's main trade partners between 2016 and 2018: The USA, Canada, Russia, Ukraine, Belarus and Brazil. These six countries account for more than 95% of the wood pellet imports to the EU since 2016. The overall composition of the EU's main trade partners in this period remains the same with some changes in the import trend.

The USA has been the largest exporter to the EU (accounting for almost 60% of the import in each year), followed by Canada (over 15% in each year) and Russia. Imports from Russia increased by about 64% from 834 ktonne in 2016 to 1,365 ktonne in 2018. Other changes in the import trend can be seen in imports from Ukraine (increased by 130% from 165 ktonne in 2016 to 380 ktonne in 2018).

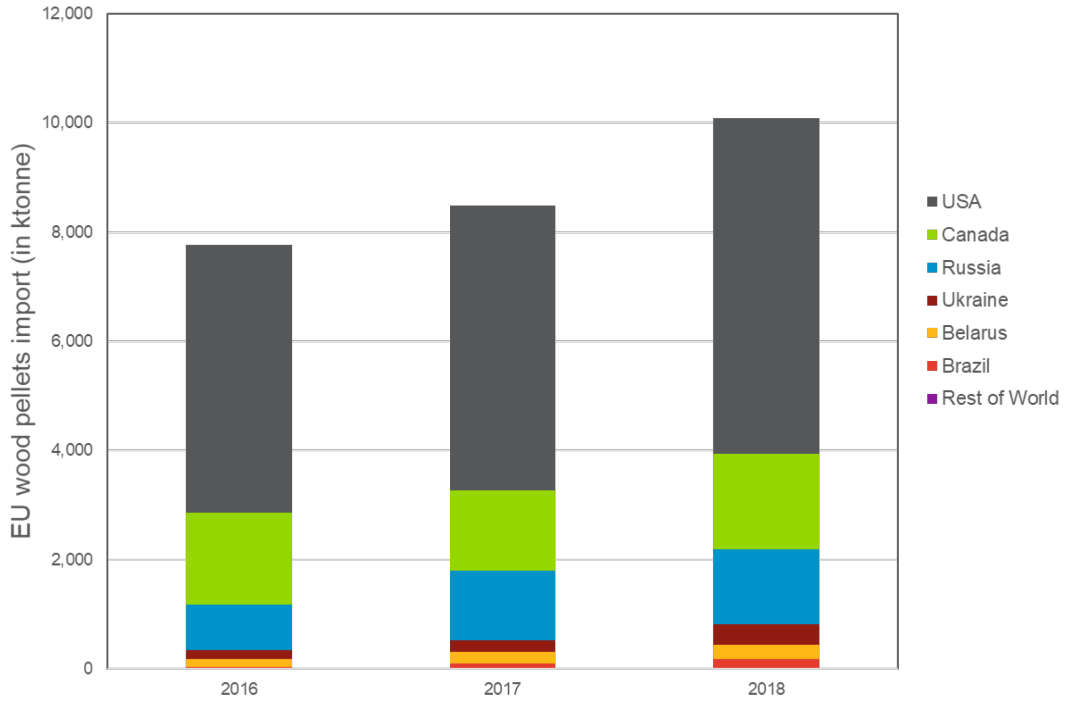

Figure 12. EU wood pellets imports from the main EU trade partners (2016 – 2018, ktonne). Source: Eurostat[81]

[79] Based on energetic value of wood pellet production and import in Eurostat nrg_cb_rw, Eurostat trade statistics on wood pellets (CN 44013100) and a LHV of wood pallets of 19 MJ/kg dry (https://publications.jrc.ec.europa.eu/repository/bitstream/JRC104759/ld1a27215enn.pdf)
[80] This information excludes intra-EU imports and indicates only imports from outside the EU28 borders.
[81] Trade statistics on wood pellets CN 44013100. This Commodity Number includes wood pellets only. Please note that the Commodity Number of wood pellets in Eurostat has changed since 2012. In 2008, the Commodity Number used was 44013090 ("Wood waste and scrap, whether or not agglomerated in logs, briquettes, pellets or similar forms, excl. sawdust"). Due to changes made by Eurostat, data between 2009 and 2011 used the Commodity Number 44013020 ("Sawdust and wood waste and scrap, agglomerated in pellets"). From 2012 and onwards, these data were reclassified into Commodity Number 44013100 ("Wood pellets").

Figure 13 presents the top Member States of wood pellets imports in 2018. The UK has been the most significant importer of wood pellets in the EU in 2018. In 2018, the UK accounted for 64% of the total EU import followed by Denmark (11%), Belgium (8%) and Italy (5%) (Figure 13). Countries such as Germany, France, Italy and Sweden represented only a small share of the EU import (collectively less than 8%) while these countries were the largest consumers of solid biomass.

The demand in these countries was mainly met by domestically produced solid biomass.[82] This is in line with the information reported by the Member States in their Progress Reports (see Appendix B).

The UK Progress Report does not give details on the sources of biomass for heat and electricity production. The Ofgem Biomass Sustainability Dataset for 2017-18[83] shows that around 25% of the solid biomass was imported from the USA and around 9% from Canada.[84] Note that 58% of the solid biomass used in the UK still originated from the UK and the remainder largely from other EU Member States.

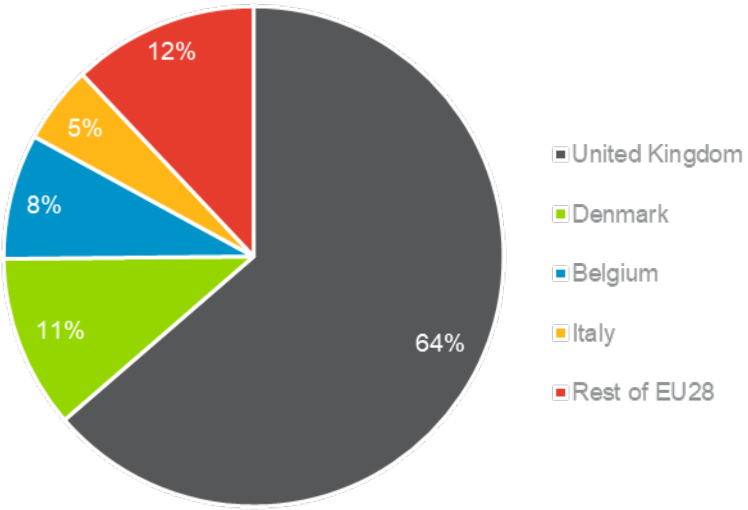

Figure 13. EU top importers of wood pellets (2018).[85] Source: Eurostat trade statistics on wood pellets CN 44013100

Wood chips import

Wood chips make up 28% of the total import of solid biomass. Figure 14 presents the EU import of wood chips in the period 2016 to 2018. The figure shows that the EU imported 6,338 ktonne of wood chips in 2018[86]. This represents an increase of 39% compared to 2016. The figure also shows the EU's main trade partners between 2016 and 2018, of which Russia and Belarus are the most significant in terms of volume. The six countries identified in the figure account for more than 94% of the wood chips imports to the EU since 2016.

The overall composition of the EU's main trade partners on wood chips in this period remained the same with some smaller changes in the import trends. Russia was the largest exporter to the EU in 2016 and 2017. As of 2018, Belarus is the main source of imported wood chips. Imports from Belarus, as the largest EU wood chips trade partner, increased by about 63% from 1,480 ktonne in 2016 to 2,419 ktonne in 2018, exceeding the overall trend of an increase in wood chips imports to Europe.

[82] Eurostat database, nrg_bal_c.
[83] https://www.ofgem.gov.uk/publications-and-updates/biomass-sustainability-dataset-2017-18
[84] The ranges represent values found in the 2015-16 and in the 2016-17 Biomass Sustainability Datasets, published by Ofgem.
[85] Top 4 importers and rest of EU28 based on percentage as EU total import.
[86] We cannot verify whether the entire imported wood chips were used for energy production since wood chips could also be used for other purposes such as producing wood pulp, as an organic mulch in gardening and landscape, etc.

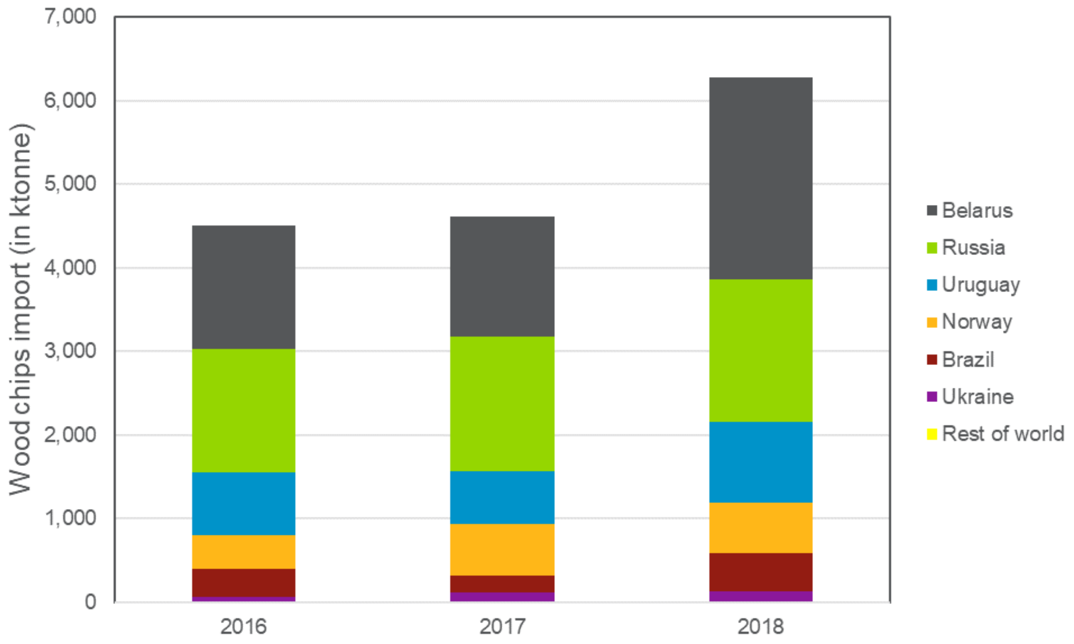

Figure 14. EU wood chips imports from the main EU trade partners (2016 – 2018, ktonne). Source: Eurostat[87]

Figure 15 shows the Member States who imported the largest volumes of wood chips in 2018. 90% of the total amount of wood chips imported to the EU took place through six Member States, namely Finland, Poland, Portugal, Lithuania, Sweden and Latvia. Finland was the largest importer of wood chips and accounted for 25% of the total EU wood chips imports in 2018. Between 2016 and 2018 Latvia showed the most notable increase of the top importers, going from 1% of total EU wood chips import to 9%, making it the sixth largest importer in the EU. Lithuania was the fourth largest importer in 2018, after Finland, Poland and Portugal (Figure 15).

[87] Eurostat trade statistics on wood chips CN 44012100 and CN 44012200. For this analysis we combined two Commodity Numbers: CN 44012100 representing coniferous wood in chips or particles (excluding those of a kind used particularly for dying or tanning purposes) and CN 44012200 representing wood in chips or particles (excluding those of kind used particularly for dying and tanning purposes, excluding coniferous wood).

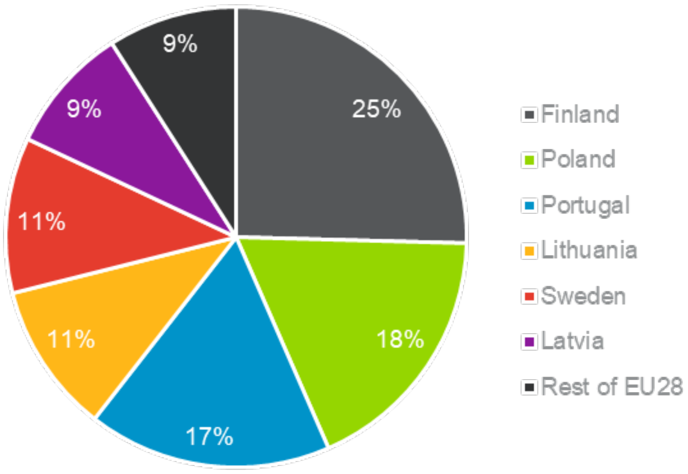

Figure 15. EU top importers of wood chips (2018). Source: Eurostat trade statistics on wood chips[88]

3.2 Biogas

3.2.1 Consumption of biogas for energy in the EU

In 2018, biogas was the third largest form of bioenergy in the EU representing a 12% share of all primary bioenergy, or 16.8 Mtoe. It is used to produce 5.2 Mtoe of electricity, 3.9 Mtoe of heat and 0.2 Mtoe of energy in transport (see Figure 2 in Chapter 2). The difference between these numbers, of 7.5 Mtoe, are losses, especially due to the efficiency of power production. In 2018, biogas is usually consumed (for heat or power production) close to its production location. The heat can be transferred directly to heat buildings and agricultural units or used in a district heating network. Alternatively, biogas can be upgraded to natural gas quality (biomethane) to be injected to the gas grid, or used directly as a fuel in the transport sector. Approximately 10% of biogas produced is currently upgraded to biomethane (2 bcm of 18 bcm).[89] In 2018, the EU consumed 154 ktoe of biogas in transport, of which 118.5 ktoe was used in Sweden and 33.4 ktoe in Germany. The high consumption in Sweden was driven by energy and CO_2 tax exemptions for biomethane in transport.

3.2.2 Production and origin of biogas for energy in the EU

Anaerobic digestion is a commercially available and widely used biological process for converting biomass into biogas in the absence of oxygen. The end-products of the process are biogas (a gas containing around 50-70% methane and 25-50% carbon dioxide,[90] water vapour and trace amounts of other gases such as oxygen, nitrogen and hydrogen sulphide) and a solid fraction called digestate. Biogas can be used to generate electricity or heat, or both outputs in a CHP system. Biogas can also be upgraded to biomethane,[91] a process in which the carbon dioxide, water and other trace gas

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[88] CN 44012100 and CN 44012200.
[89] Gas for Climate, *Gas Decarbonisation Pathways 2020-2050*, https://gasforclimate2050.eu/publications.
[90] Biogas from sewage digesters usually contains from 55 to 65% methane, 35 to 45% carbon dioxide and <1% nitrogen, biogas from organic waste digesters usually contains from 60 to 70% methane, 30 to 40% carbon dioxide and <1% nitrogen, while in landfills methane content is usually from 45 to 55%, carbon dioxide from 30 to 40% and nitrogen from 5 to 15% [Rasi S 2009, Biogas composition and upgrading to biomethane, University of Jyväskylä Finland].
[91] Biomethane is a purified form of biogas, with higher methane content. The exact methane content may depend on the location and application. In the Netherlands, biogas with at least 85% methane can be injected in the gas grid, and could thus be called biomethane, while in Sweden, over 97% purity is required [Rasi S 2009, Biogas composition and upgrading to biomethane, University of Jyväskylä Finland].

impurities are removed. Biomethane has an additional advantage, namely that it can be injected into existing gas infrastructure, or used as a transport fuel.

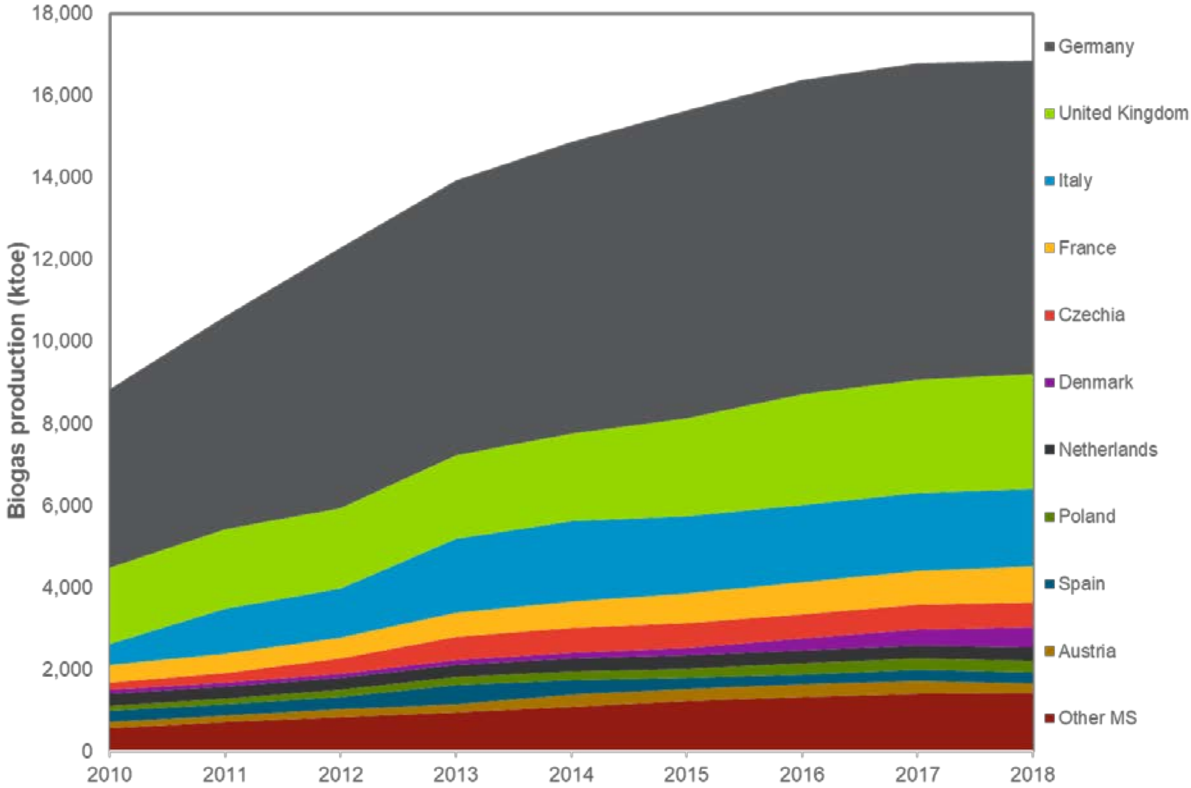

Figure 16. EU biogas production (2010 – 2018, ktoe).[92] **Source: Eurostat nrg_bal_c**

Biogas production in the EU has two main purposes: it is either seen as a method for waste treatment or a way of energy production. It can also be used for a combination of the two purposes. Germany has been the frontrunner in biogas production to date accounting for 45% of the total EU production in 2018, followed by the UK (17%), Italy (11%), France (5%) and Czechia (4%).

The number of biogas plants in the EU increased from 12,397 installations in 2011 to 17,439 in 2016 to 18,202 in 2018, with biogas production following this growth trend.[93] As shown in Figure 16, biogas production experienced a significant growth of 56% from 2011 to 2016 with production then flattening from 2016 to 2018, with Germany as strongest driver for this change in trend. In Germany several incentives, including the Renewable Energy Act (EEG), Renewable Energy Bonus, CHP bonus, technology bonus and KfW renewable energies programme, have been in place to support investments in biogas anaerobic digesters.[94] The most effective driver for the production of biogas/biomethane was the Renewable Energy Act, which originally came into force in 2000 and has since then been modified several times. It includes a guaranteed feed-in tariff for the generated electricity from biogas, which was initially set higher than that of electricity generated from other renewable sources. However, amendments made to the Renewable Energy Act in 2014 cancelled specific biogas related targets for 2020 and 2030 and as a result, there was a slowdown in the construction of new biogas plants.

[92] Data are shown for the 10 Member States with the largest production volume in 2018. The other Member States are aggregated.
[93] European Biogas Association (EBA): https://www.europeanbiogas.eu/eba-statistical-report-2019/
[94] Biogas & biomethane in Europe, European Biomass Association: https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/agriforenergy_2_international_biogas_and_methane_report_en.pdf

In the UK, the most effective incentives for production of biogas/biomethane since 2011 are the Feed-in Tariffs scheme for electricity (2010) and the Renewable Heat Incentive (2011). These incentives have resulted in a significant growth of the UK biogas sector, in particular between 2011 and 2013. In Italy and Czechia, the most important driver has also been a feed-in tariff. Notably though, biogas production in Italy has decreased since 2014 due to the reduction of the feed-in tariff.[95] Italy could see an increase in the coming years because a subsidy was introduced for biomethane used as a transport fuel in the beginning of 2018. The subsidy is for plants beginning operations between 2018 and 2022 and has a total budget of 4.7 billion euro. [96]

The production of biogas is assessed in more detail in Figure 17. With 45% of all biogas production, Germany is the largest EU biogas producer. 92% of German biogas is produced from anaerobic digestion of agriculture wastes, residues and crops (manure, maize and hay silage and sugar beet). In the UK, the second largest EU biogas producer with 17%, around 45% of biogas is produced from agricultural products and the biggest share (around 55%) comes from landfill and sewage sludge gases. The potential of landfill gas in the UK will depend on how waste trade is handled with the withdrawal of the UK from the EU. Although historically there has been a reduction in landfills and therefore landfill gas, the UK currently exports waste to other Member States such as Germany and the Netherlands. If this trade is affected or disrupted by 'Brexit', the UK could be forced to increase the volume of waste landfilled.[97] Italy follows with 11% of biogas production, mainly from manure and energy crops, with a small contribution from landfill gas.

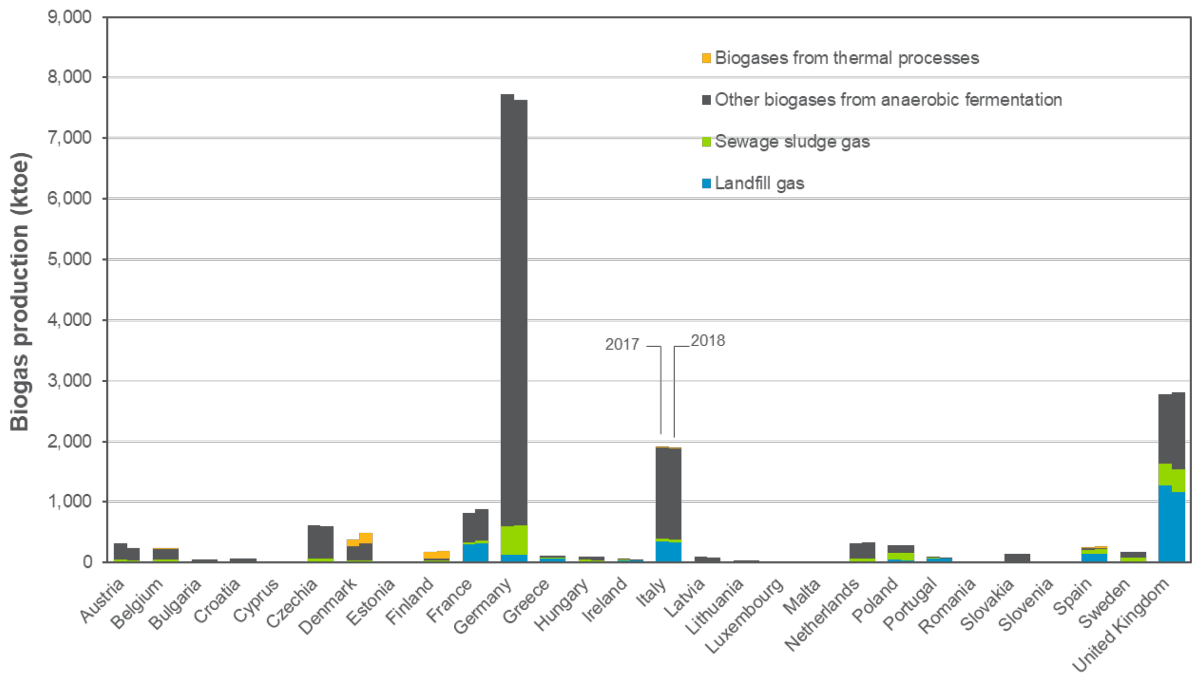

Figure 17. National biogas production per sources (2017 – 2018, ktoe).[98] Source: Eurostat nrg_cb_rw

Table 7 shows biogas production in the EU between 2010 and 2018, differentiated by feedstock types.[99] The amount of biogas produced from landfill has decreased since 2013 as the share of waste disposed to landfill decreased due to several Member States imposing higher landfill taxes. On the

[95] Optimal use of biogas from waste streams, European Commission, 2016: https://ec.europa.eu/energy/sites/ener/files/documents/ce_delft_3g84_biogas_beyond_2020_final_report.pdf
[96] Gas for Climate, *Gas Decarbonisation Pathways 2020-2050,* Table 1, https://gasforclimate2050.eu/publications.
[97] https://www.bbc.com/news/business-49440290
[98] "Other biogases from anaerobic fermentation" mainly represents biogas from manure and energy crops like corn silage.
[99] These data are from Eurostat and are given in rather aggregated forms since information of specific feedstock use for biogas production is often not easy to obtain.

other hand, biogas production from anaerobic digestion and thermal processes increased. In 2018, biogas from farm-based plants (mainly silage maize), manure and other agro/industrial organic wastes had a share of 75%, whereas biogas from landfill had a share of 14%, biogas production from sewage sludge had a share of 9% and biogas from thermal processes had a share of 2%.

The share of biogas from thermal processes is negligible, but shows a relatively steep growth, since these technologies are still in the development stage.

Table 7. Feedstock for biogas production in the EU (ktoe). Source: Eurostat, nrg_cb_rw

Product	2010	2011	2012	2013	2014	2015	2016	2017	2018
Other biogases from anaerobic fermentation1)	4,881	6,441	8,082	9,522	10,506	11,317	12,039	12,473	12,575
Landfill gas	2,840	2,924	2,912	2,971	2,906	2,837	2,742	2,585	2,429
Sewage sludge gas	1,114	1,220	1,262	1,378	1,371	1,369	1,439	1,469	1,509
Biogases from thermal processes	0	22	28	61	85	99	160	260	326
Total biogas	**8,835**	**10,607**	**12,284**	**13,932**	**14,868**	**15,622**	**16,379**	**16,786**	**16,839**

1) Eurostat nrg_cb_rw includes the category “Other biogases from anaerobic fermentation” as third (but largest) category after “Landfill Gas” and “Sewage Sludge Gas”. This includes biogas on basis of manure, agriculture/food/industry waste and field crops such as corn silage.

Nearly all the biogas that was produced in the EU has been consumed domestically.[100] The precise geographical origin of the materials from which the biogas has been produced could not be assessed. Most of these materials are wastes with a high moisture content and are costly to transport over a long distance. The energy crops that have been used (often as a co-digestate) in anaerobic digestion are generally produced on or near the farm where the biogas production takes place, since it is not economically attractive to procure such crops from further away.

3.3 Bioliquids

Electricity from bioliquids accounts for a small share (3%) of the total bioelectricity generated in the EU and less than 1% of all bioenergy. Table 1 in Chapter 2 showed that bioliquid use in the EU in 2018 is at the same level as in 2010, with lower use in 2011-2014 and higher use in 2015-2017. Bioliquids for electricity generation were mainly deployed in five Member States: Italy (369 ktoe), Germany (41 ktoe), Belgium (6 ktoe), Sweden (4 ktoe) and Spain (1 ktoe).[101] Whereas in Italy bioliquids account for a large share of domestically produced bioelectricity (22%), in Germany, Belgium and Austria they only account for a very small fraction (<3% in each Member State).

Since bioliquids have a small share in bioelectricity (as well as in heat) generation, the information on the type of bioliquids is limited. The Member States’ Progress Reports do not differentiate between feedstock used for biofuels and bioliquids, presenting both of these feedstocks under the same category.

3.4 Liquid biofuels

The consumption of liquid bioenergy carriers in the EU accounts for 16.8 Mtoe, or 13% of all bioenergy and 8% of all renewable energy (in all sectors). Liquid bioenergy largely concerns biofuels in transport (16.7 Mtoe) and for a smaller part bioliquids, i.e. liquid forms of bioenergy used for power production in conventional thermal power stations and of heat and power in CHP stations (as described above in Section 3.3). Because the sustainability of bioenergy in the frame of the Renewable Energy Directive especially concerns biofuels in transport, their feedstock and origin are assessed in more detail in Chapter 4.

[100] Eurostat nrg_bal_c.
[101] Eurostat nrg_bal_c.

3.5 Renewable fraction of municipal solid waste

The contribution of the renewable fraction of municipal solid waste (MSW) to the gross bioenergy consumption was 7% in 2018, see Figure 1 in Chapter 2. The contribution of the renewable fraction of MSW in the energy sector has slowly increased over the past decade, from 7.4 Mtoe in 2007 to 10.4 Mtoe in 2018. MSW is currently only used to produce heat (3 Mtoe according to Eurostat,[102] although not reported by all Member States in their Progress Reports) and power (net 2 Mtoe renewable electricity). Germany, France and the Netherlands have continuously been the main users of MSW for energy generation since 2007.

Figure 18 shows the historical trend of the main EU consumers of MSW (renewable fraction) in the power sector. The figure indicates a growing trend since 2010 in all main Member States, except in Sweden where the amount remained relatively stable. Germany shows a constant and rapid growth over time (30% between 2010 and 2018) and the UK shows a steady increase from 2014 as a result of high landfill charges and increase in incineration capacity. In 2018, Germany was by far the largest consumer of MSW for power generation, accounting for 27% of the EU consumption followed by the UK (16%), Italy (10%), France (10%), the Netherlands (9%) and Sweden (7%).

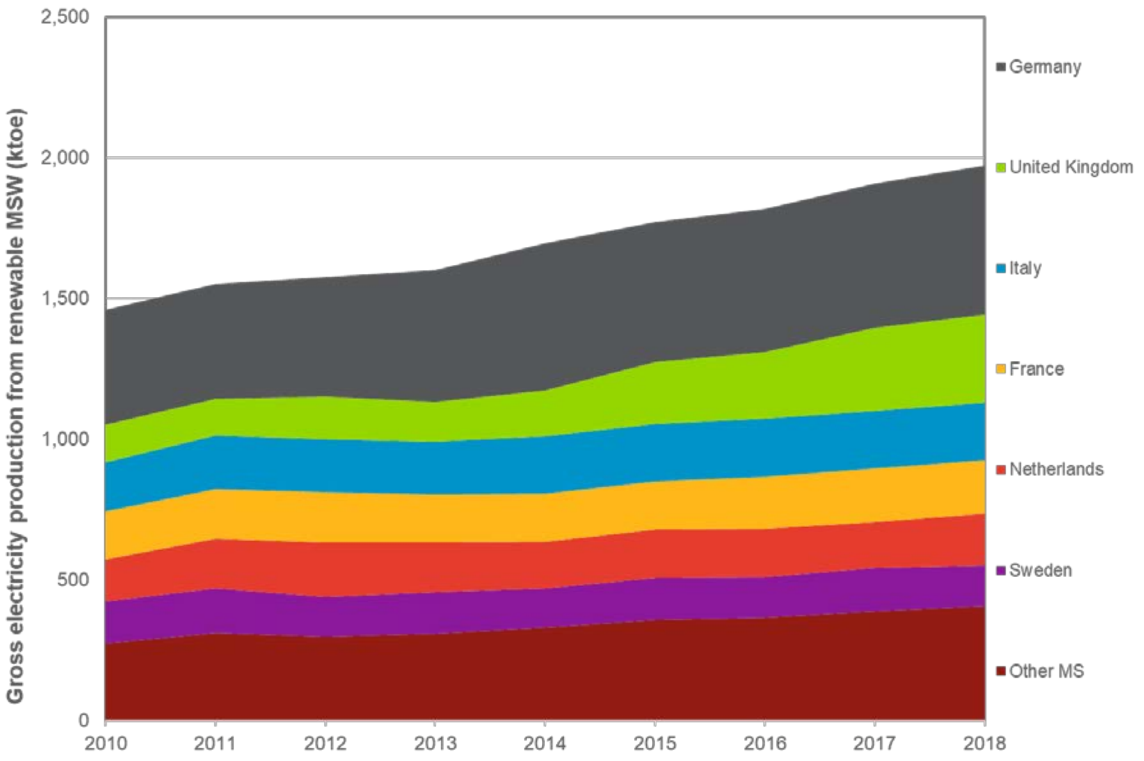

Figure 18. Consumption of the organic fraction of Municipal Solid Waste (MSW) in the power sector in selected MS. Source: Eurostat nrg_bal_c

Table 21 in Appendix A, gives an overview of the information reported by the Member States on the share of renewable waste in the waste used for energy production. Also included are any remarks provided by Member States on the methodologies applied for estimation and any steps taken to improve these estimates. As indicated, several Member States did not report the actual share they applied in 2017 and 2018. Additionally, several Member States did not report any renewable energy produced from MSW (e.g. Austria, Cyprus, Chechia, France, Ireland, Latvia, Lithuania, Slovenia and the UK), while others did report renewable energy produced from MSW, but not the fraction applied

[102] Eurostat nrg_bal_c reports that the gross heat production from the renewable fraction of municipal solid waste in the EU in 2018 was 3 Mtoe. This is not visible in Figure 2, since heat in Figure 2 is based on Member State reports as explained in Footnote15.

(e.g. Bulgaria and Greece). For the Member States that did report the renewable fraction in their Progress Reports, most indicated a share between 50-60%. Several Member States refer to regulation, or online documentation, in which methodologies to assess the renewable fraction are detailed.

Many Member States use measurements or sampling in a selection of processing facilities to determine the renewable fraction of MSW, elaborate on methodologies applied to determine (e.g. C14 method) and mention regular assessments on this.

MSW consumed in EU bioenergy production originates almost exclusively from the EU.[103] As mentioned in Section 2.2, MSW and (actually mostly) its derivatives RDF/SRF are however traded within the EU between Member States.

[103] In 2017 and 2018, the import of municipal waste from third countries to the EU customs union represented less than 0.01% of the EU internal waste production. Moreover, over 95% of this import was from Gibraltar [Eurostat trade statistics on wood pellets HS 382510].

4. Feedstock for biofuels and their origin

4.1 Biofuels consumption in the EU

Figure 19 shows biofuel consumption per fuel type for the period 2010-2018. Most biofuels consumed in the EU constitute of biodiesel (77%, FAME or HVO) or bioethanol (16%).[104] Other liquid biofuels (6%) are not specified. Almost all biofuels are consumed in the road transport sector, while the use in aviation and shipping is negligible. About 35% of all the biofuels are consumed in just two Member States, Germany and France.

Over the period 2011-2016, the consumption of biodiesel has been rather stable, between 11 and 12 Mtoe. The consumption of bioethanol shows a slow decrease over the same period. After this period of slight decline, consumption of both biodiesel and bioethanol has increased from 2016-2018, driving a compound annual growth rate of 10% in the period 2016-2018.

About 41% of the biodiesel consumed in the EU in 2018 comes from EU feedstock, mainly from rapeseed (26%), UCO (8%) and animal fat (5%). The main third countries of origin are Indonesia (17%) and Malaysia (8%), whose palm oil ends up in EU consumed biodiesel, and Argentina (9%) which exports biodiesel made from soybeans.

Around 73% of the bioethanol consumed in the EU in 2016 comes from EU feedstock. This mainly concerns wheat (34%), maize (24%) and sugar beet (14%).

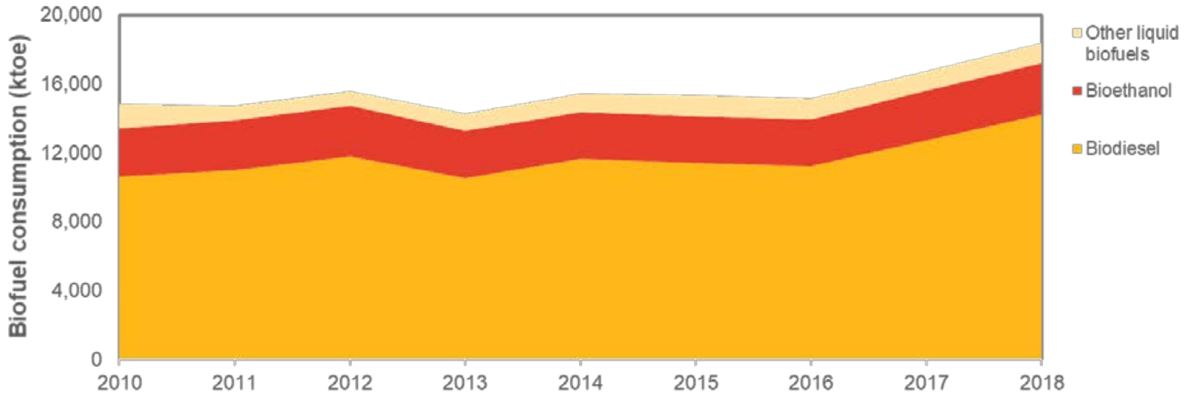

Figure 19. Liquid biofuel consumption per fuel type (2010 – 2018, ktoe). Source: Eurostat nrg_bal_c

4.1.1 Biodiesel (FAME and HVO)

Biodiesel represents the majority of biofuels consumed in the EU, with a share of about 77% of the total transport biofuel market (compare Figure 20 and Figure 21).[105] Figure 20 presents biodiesel consumption in the EU between 2010 and 2018. Based on the available data, one cannot distinguish between HVO and FAME consumption in the EU market, although based on the production capacities in the EU and major third country producers (see Section 4.4), it could be estimated that in 2018 81% concerns FAME and 19% concerns HVO.[106]

With increasing HVO production in France (Total) and Italy (ENI) this figure is expected to shift to

[104] Source: Eurostat nrg_bal_c. The terms biodiesel and bioethanol refer to the physical appearance of the fuel. Biodiesel is a type of fuel that can be blended with diesel. The main types of biodiesel are Fatty Acid Methyl Ester (FAME) and Hydrotreated Vegetable Oil (HVO). Ethanol is the chemical name of what is commonly known as alcohol. It can be blended with gasoline. These terms have no relation to the sustainability of biofuels, and are also unrelated to the categories “compliant biofuels” or “Annex IX biofuels”.
[105] Eurostat data, nrg_bal_c
[106] USDA GAINS Report, *EU Biofuels Annual 2019.* Table 9.

70/30 in the coming years. Figure 20 presents the ten largest EU consumer markets, while the figures for the other Member States are aggregated. After the strong growth in biodiesel consumption in the first decade, the consumption in the EU has been rather stable from 2012 to 2016, between 11 and 12 Mtoe, with only a temporary dip in 2013. The stabilisation relates to the introduction of double counting biofuels, which allowed for an increasing RES-T share over the same period, while the biofuels volume in total hardly increased. This was discussed in Section 2.3. In 2017 and 2018, we again see an increase in the biodiesel consumption.

The following trends can be observed from Figure 20:

- A rapid biodiesel uptake is observed between 2011 and 2012 in most of the key markets. This increase was mainly due to an increase in mandates in some Member States. The largest growth was observed in Spain where the biodiesel specific mandates increased from 3.9% to 7%.[107]
- A 10% decline is observed in 2013. This can largely be explained by two factors: double counting and reduced mandates in some Member States. Double counting of advanced biofuels was applied in Germany (2011-2014), Italy (2012 until early 2014), the Netherlands, Belgium, the UK, Portugal and Austria. Double counting reduces the physical biofuels volume that is required to meet the mandates. In addition, Spain reduced its consumption mandates from 7% down to 4.1% at the beginning of 2013.[107]
- From 2013 through 2014, the overall consumption of biodiesel in the EU increased, largely due to increases in France, Germany, Sweden, the UK and Austria.
- From 2014 through 2016 biodiesel consumption fluctuated as mandate increases in some Member States[107] were off-set by consumption decreases in other Member States. During this period, the biodiesel consumption decreased in Germany, the UK, and Czechia and increased in Sweden and several other Member States. The decrease in Germany is due to the transition from an energy-based consumption mandate to greenhouse gas reduction mandates in 2015. Based on this new regulation, companies are encouraged to calculate actual greenhouse gas values rather than using default values and to use biofuels with higher emission savings. This reduces the physical volume of biofuels required to reach the mandates. In Czechia an increase in the excise tax for biofuels made biodiesel more expensive compared to fossil diesel.[108] In Sweden, biodiesel consumption benefitted from tax exemptions and higher mandates for biofuels in diesel (19.3% on energy basis).[109]
- A rapid biodiesel uptake is observed between 2016 and 2018. The strongest growth comes from Spain (559 ktoe), Sweden (484 ktoe) and Poland (450 ktoe). The relative growth has been strongest in the Netherlands and Poland, where biodiesel consumption more than doubled since 2016.
- From 2017 to 2018 there is an increase in consumption due to national mandate increases in Finland, the Netherlands, Poland, Spain and the UK.

Biodiesel (FAME and HVO) consumption is driven almost exclusively by Member State mandates and less so by tax incentives.[110] With increasing mandates to 2020 and onwards, this triggers the increasing biodiesel consumption observed in recent years.

[107] Overview of the biofuel policies and markets across the EU-28, ePURE, 2016.
[108] Czech Republic case study, European Environment Agency:
[109] https://green-budget.eu/green-overhaul-of-swedish-fuel-and-vehicle-taxation/
[110] See 'Technical assistance in realisation of the 4th report on progress of renewable energy in the EU', Navigant, a Guidehouse company, 2020.

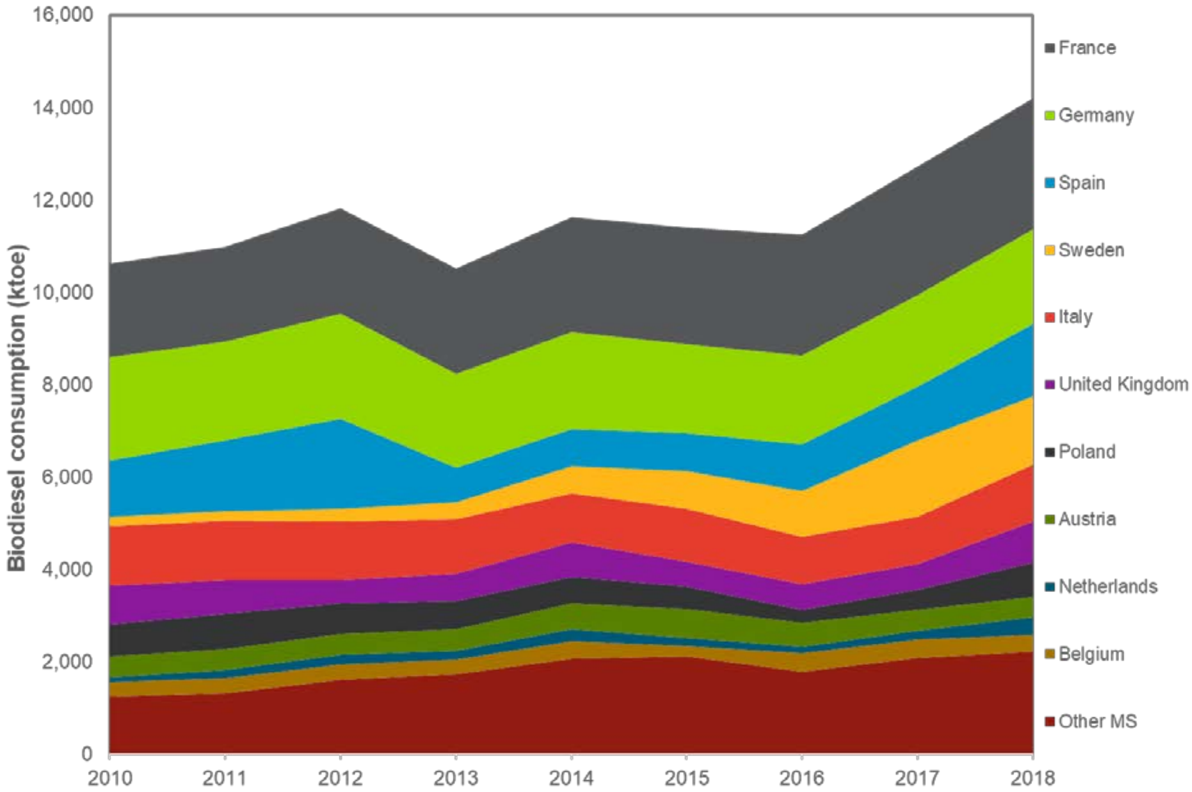

Figure 20. Biodiesel consumption in the EU28 (2010 – 2018, ktoe). Source: Eurostat nrg_bal_c.[111]

4.1.2 Bioethanol (Ethanol and ETBE)

Figure 21 shows bioethanol consumption in the EU between 2010 and 2018. The figure shows the ten largest EU consumers and separates them from the rest of the Member States. As can be seen from this figure, bioethanol consumption shows a declining trend in the EU between 2010 and 2016. This can mainly be explained by the double counting of bioethanol, which reduces the physical volume of bioethanol required to reach the mandate, lower gasoline consumption in the EU[112] (115 million litres in 2011 versus 102 million litres in 2016) and the adjustment of national bioethanol specific blending mandates. From 2016 to 2018, the bioethanol consumption increased. Similar to biodiesel, this can be explained by the increasing biofuel mandates in many Member States. In addition, bioethanol was more competitive with gasoline prices and imports from the USA increased (463 million litres in 2018 compared to only 45 million litres in 2016).[113]

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[111] Data are shown for the 10 Member States with the largest consumption volume in 2018; The other Member States are aggregated.
[112] Eurostat database.
[113] USDA GAINS Report, *EU Biofuels Annual 2019.*

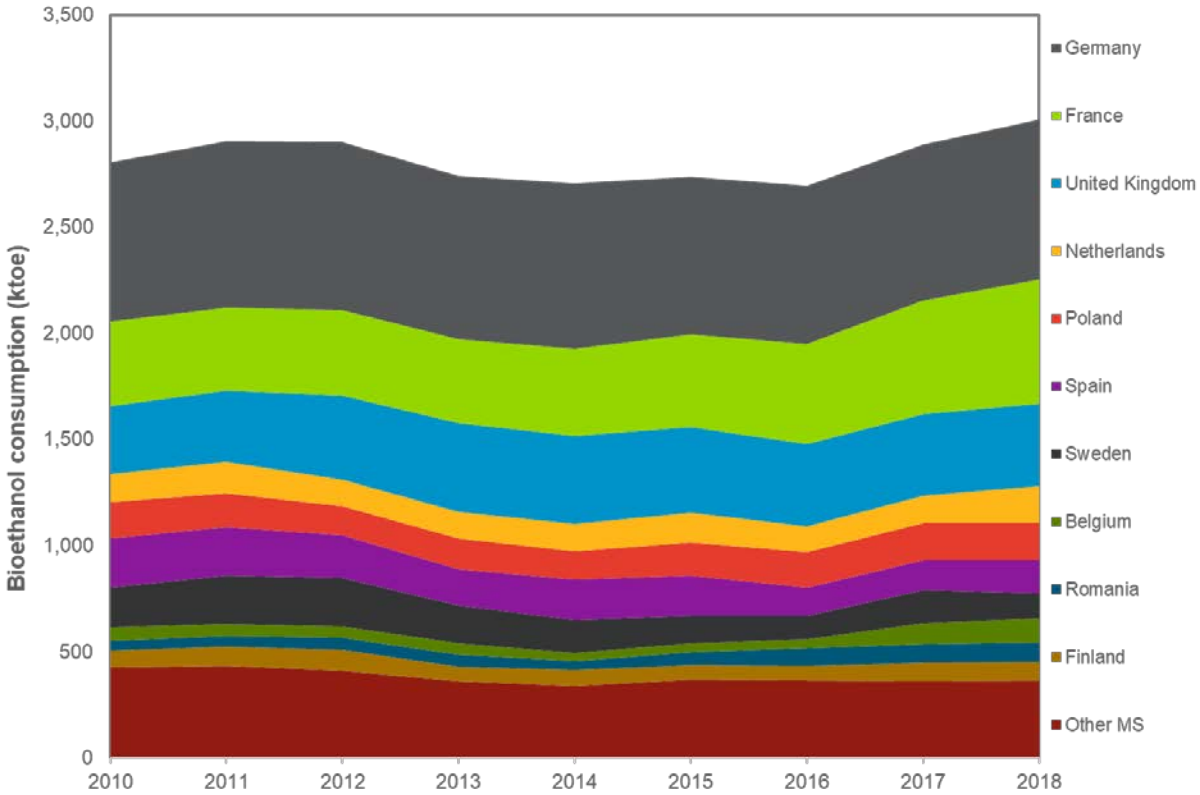

Figure 21. Bioethanol consumption in the EU28 (2010 – 2018, ktoe).[114] Source: Eurostat nrg_bal_c

[114] Data are shown for the 10 Member States with the largest consumption volume in 2018; The other Member States are aggregated. Note: Eurostat reports the consumption of biogasoline. The largest part of this product is bioethanol or its derivative bio-ETBE.

4.2 Biofuels production in the EU

4.2.1 Biodiesel (FAME and HVO)

Figure 22 shows biodiesel production (FAME and HVO) in the EU between 2010 and 2018, including the ten largest producing Member States. In 2018, about 81% (on mass basis) of the biodiesel produced in the EU was FAME biodiesel, and the remainder was HVO biodiesel.[115]

Biodiesel production in the EU had an increasing trend between 2011-2014, followed by a slow decrease towards 2016 and an increasing trend again from 2016 onwards. In 2014, EU biodiesel production benefited from higher domestic consumption and higher exports.[116] As a result, biodiesel production increased in most of the Member States, most significantly in Spain, Belgium, the Netherlands, Germany and France.[117] The slight production decline in 2016 as compared to 2014 is mainly attributed to the decline in biodiesel consumption and competition from imports (import to the EU was 6.7 Mtonne in 2016 versus 6.6 Mtonne in 2014).[118]

From 2016 to 2018, the increase in biodiesel production is mainly attributed to the increase in FAME production, while HVO production remained stable. However, HVO production will increase in 2019 with the opening of a biorefinery producing HVO in France and another one in Italy. The slight increase in production in Spain could be explained by the increase in biofuel mandates which increase from 2016 to 2020, creating further demand.[119]

The EU biodiesel market is mainly driven by domestic consumption and import competition. While HVO is not imported (or at least negligible amounts according to industry traders), import competition does influence FAME production. In 2018, 42% of imported biodiesel came from Argentina (soy) and 27% from Indonesia (palm). These cheap imports rapidly increased from 2017 to 2018 which drove down EU production. This was due to the removal of anti-dumping duties from Argentina in September 2017 and Indonesia in March 2018, which had been imposed since March 2013.[120]

FAME is produced in all Member States except for Finland, Luxembourg and Malta while HVO is only produced in the following six Member States: the Netherlands, Finland, Spain, Italy, Sweden, France and Portugal. Although Germany was the largest total biodiesel producer in 2018, France was the largest biodiesel consumer in the same year (compare Figure 20 and Figure 22).

[115] USDA GAINS Report, *EU Biofuels Annual 2019*. Table 9.
[116] Eurostat, nrg_cb_rw.
[117] Eurostat, nrg_bal_c.
[118] Eurostat, nrg_t.
[119] http://agriexchange.apeda.gov.in/MarketReport/Reports/Spain%E2%80%99s_Biodiesel_Renewable_Diesel_Overview%20_Madrid_Spain_6-27-2017.pdf

[120] USDA GAINS Report, *EU Biofuels Annual 2019.*

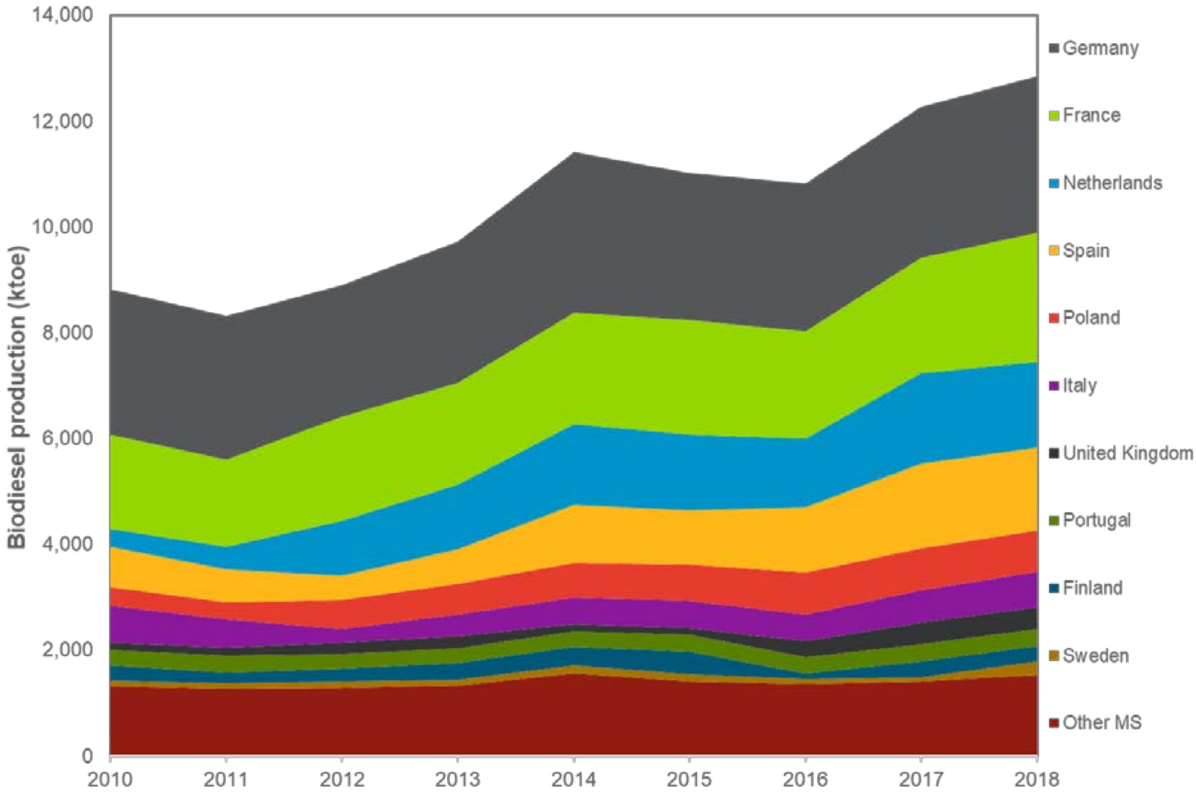

Figure 22. Biodiesel production in the EU28 (2010 – 2018, ktoe).[121] Source: Eurostat nrg_bal_c

4.2.2 Bioethanol (ethanol and ETBE)

Although the EU is today the third largest bioethanol producer in the world, it remains a modest player with only 0.8% of the total global ethanol production in 2018. The USA and Brazil are the two largest producers, representing 92% and 7% respectively of global production. [122] Figure 23 shows bioethanol (ethanol and ETBE) production in the EU from 2010 through to 2018. The figure displays the ten largest EU producers and separates them from the rest of Member States (which are presented aggregated). While EU bioethanol consumption has declined from 2011 to 2016 (Figure 21), the production has shown an increasing trend with a peak in 2013. In 2013, EU ethanol production benefitted from lower feedstock prices and more stringent import measures, thus bioethanol production reached more than 2,500 ktoe (equal to about 5 billion litre). The import measures included both tariff (€ 0.19/litre) and non-tariff measures. Implementation of non-tariff measures such as sustainability criteria have significant potential to limit the bioethanol imports to the EU.

The decline from 2013 through 2015 is due to a shrinking domestic market caused by the competition of double-counting of waste-stream biodiesel, high import duties, and changes to blending mandates in some Member States (e.g. the introduction of E10). The production dropped most significantly in the UK, Belgium, the Netherlands and France.

Overall, from 2016 to 2018, EU bioethanol production increased because of the increasing demands of Member States as they attempt to meet their 2020 RES-T targets. Some Member States however

[121] Data are shown for the 10 Member States with the largest production volume in 2018. The other Member States are aggregated.
[122] https://www.statista.com/statistics/281606/ethanol-production-in-selected-countries/

experienced a decrease in production from 2017 to 2018, most notably Germany and the UK. The German Bioethanol Industry Association attributes the decline in production to the increase in crop prices caused by the drought experienced in 2018. In the UK, the decline could be explained by competition with waste-based biodiesels and the gradual decline of the cap on crop-based fuels.[123]

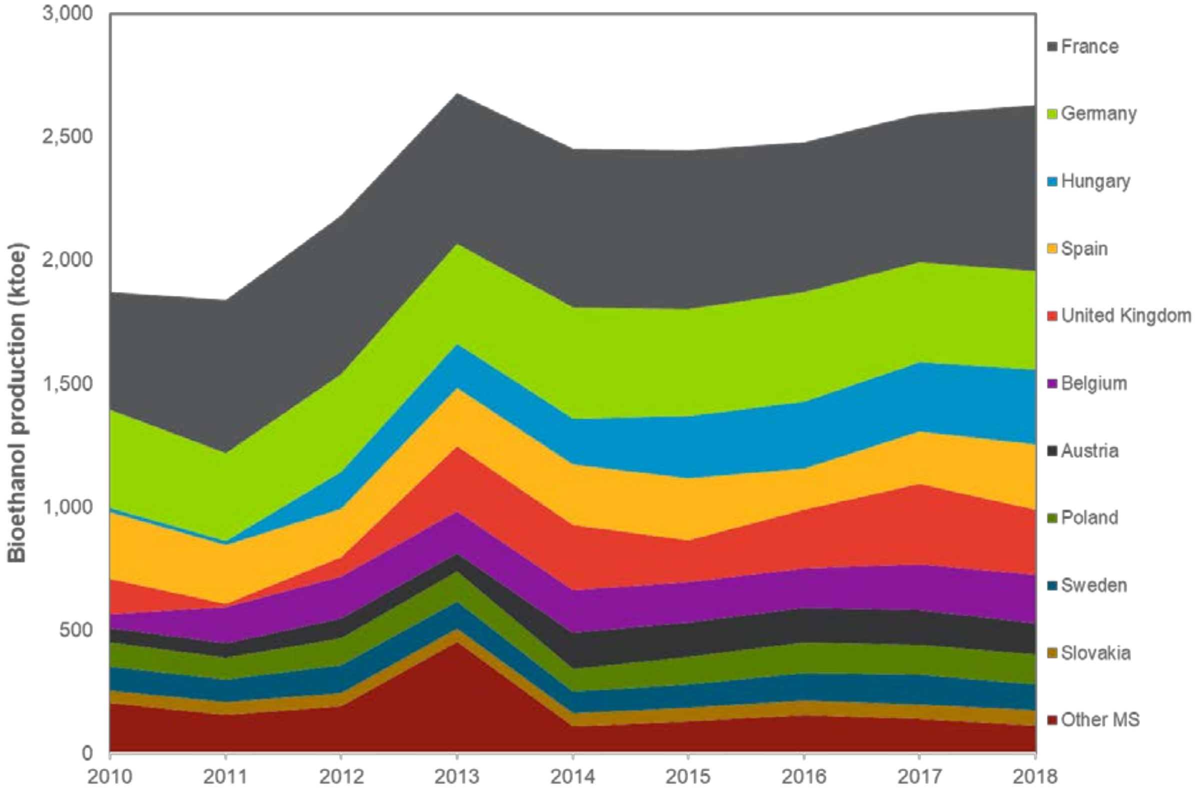

Figure 23. Bioethanol production in the EU28 (2010 – 2018, ktoe).[124] Source: Eurostat nrg_bal_c

4.3 Annex IX biofuels

The use of waste streams or residues as feedstocks for biofuels are likely to cause less sustainability impacts than traditional agricultural crops. Likewise, lignocellulose feedstocks such as energy grasses could be produced with less sustainability impacts. These so called "advanced" biofuels, based on biomass waste and residues, typically have high greenhouse gas emissions savings (compared to the fossil comparator) and a low indirect land use change (ILUC) impact[125]. For this reason, the Renewable Energy Directive sets separate goals for biofuels produced from these types of feedstock or attributes a higher value in the form of double counting. Two types of feedstock are examined in this section:

- Annex IX A type biofuels, which are produced from a range of very different feedstocks (including gaseous fuels).
- Annex IX B type biofuels, which are produced from used cooking oil (UCO) or animal fat.

[123] USDA GAINS Report, *EU Biofuels Annual 2019.*
[124] Data are shown for the 10 Member States with the largest consumption volume in 2018; The other Member States are aggregated. Note: Eurostat reports the consumption of biogasoline. The majority of this product is bioethanol or its derivative bio-ETBE.
[125] See detailed results in the GLOBIOM studies, available from the EC website:
https://ec.europa.eu/energy/sites/ener/files/documents/Final%20Report_GLOBIOM_publication.pdf and
https://ec.europa.eu/energy/sites/ener/files/documents/globiom_complimentary_2016_published.pdf

The ILUC Directive includes a national sub target of 0.5% for biofuels produced from Annex IX Part A feedstocks.[126] Part B of Annex IX includes a separate list of waste feedstocks (namely UCO and animal fats categories 1 and 2). Biofuels produced from both Part A and Part B Annex IX feedstocks count twice towards a Member State's 10% RES-T target. In addition, the ILUC Directive also sets a cap of 7% on the use of food and feed crop-based biofuels in transport.

In December 2018, the recast of the Renewable Energy Directive (REDII) was published, covering the period 2021-2030. The new Directive specifically promotes the consumption of advanced biofuels with the following provisions[127]:

- Biofuels produced with feedstocks listed in Part A of Annex IX shall at least have a share of final consumption of energy in the transport sector of 0.2% in 2022, rising to 1% in 2025 and 3.5% by 2030.
- Biofuels produced with feedstocks listed in Parts A or B of Annex IX may be double counted towards a Member State RES-T target.
- With the exception of fuels produced from food and feed crops the share of fuels used for aviation and maritime are counted 1.2 times.
- The share of food and feed crop-based biofuels in transport shall be no more than 1% higher than the share of such fuels in the final consumption of energy in the road and rail transport sectors in 2020 in that Member State, with a maximum of 7% of final consumption of energy in the road and rail transport sectors in that Member State.[128]

Based on the above proposed elements and the EC support programs for the commercialization of Annex IX A biofuels[129], the production and consumption of advanced biofuels in the EU are expected to increase beyond 2020.

Increasingly, biofuels are produced from waste and residues as demonstrated by the increased consumption of double counting biofuels, as discussed in Section 2.3 and shown in Figure 8. In the biodiesel sector, this can be both FAME and HVO on the basis of UCO or animal fats or HVO on the basis of tall oil. Other types of Annex IX A feedstock are not yet widely used in biodiesel.

Cellulosic bioethanol is an advanced biofuel that has been promoted by several companies in the EU. However, the market has been slow to develop due to various reasons (technical and/or financial) and some previously operational plants have ceased operation. Beta Renewables, for example, closed operations of its cellulosic ethanol plant in 2017 due to the bankruptcy of its parent company[130] and Abengoa similarly sold their assets in a plant in Spain in 2016.[131] Also outside the EU some operational plants have had to cease operation. [132]

There are still, however, several cellulosic ethanol projects underway, including the St1 Biofuels Oy demonstration plant in Kajaani Finland (10 million litres annual capacity) which began in 2017 to use residual sawdust from the forestry sector and test the profitability of cellulosic ethanol production.[133] Clariant is also very active in this space and has signed several license agreements for its Sunliquid technology for cellulosic ethanol plants from agricultural residues (such as straw) in Slovakia and Romania (annual capacity 50,000 tonnes each), and most recently in Poland (annual capacity 25,000 tonnes).[134]

[126] Member States shall endeavour to achieve the target and can also set a lower target if justified.
[127] Please note that the REDII further introduces a cap on the use of Part B Annex IX fuels.
[128] Member States can set a lower target "taking into account best available evidence on ILUC impact" and differentiate by crop type.
[129] E.g. Innovating for sustainable growth: a bioeconomy for Europe; Bio-based industries joint undertaking.
[130] http://www.biofuelsdigest.com/bdigest/2017/10/30/beta-renewables-in-cellulosic-ethanol-crisis-as-grupo-mg-parent-files-for-restructuring/
[131] USDA GAINS Report, *EU Biofuels Annual 2019.*
[132] For example POET-DSM in the US: https://cen.acs.org/business/biobased-chemicals/POET-DSM-pause-cellulosic-ethanol/97/i46
[133] https://forest.fi/article/st1-aims-to-increase-its-production-of-wood-based-bioethanol-15-fold-by-products-of-forest-industry-replace-fossil-raw-materials-and-increase-carbon-sink-in-agricultural-lands/
[134] https://www.chemanager-online.com/en/news-opinions/headlines/clariant-licenses-second-sunliquid-plant

4.4 Origin of feedstock used for biofuels consumed in the EU

4.4.1 Origin of biofuel feedstock

This section presents the estimated origin of the main feedstocks used to produce biodiesel and bioethanol consumed within the EU. This information is estimated by combining the biofuel trade statistics from Eurostat with statistics and estimations of feedstock for biofuels in all biofuel producing countries, as well as trade statistics of the major feedstocks.

Table 8 shows the origin of feedstock used for EU biodiesel consumption in 2018. The largest part of biodiesel by volume (41%) is estimated to be based on domestic feedstocks, mainly from rapeseed (26%), UCO[135] (8%) and animal fat (5%). In 2018, additional UCO was imported from South East Asia (in particular China), the USA and multiple other countries. Over 20% of the EU biodiesel volume originates from palm oil, mainly from Indonesia (11% of the EU consumed biodiesel) and Malaysia (4%). A smaller fraction is imported in the form of biodiesel from Indonesia (4% of the EU consumed biodiesel) and Malaysia (2% of the EU consumed biodiesel).

In comparison, in 2016[136] similar analysis indicated over 60% of the biodiesel to be based on EU feedstocks. Also, in absolute terms (5,871 ktoe in 2018 versus 7,062 in 2016), the share of the EU feedstocks went down. The main increase in share (both percentage as well as absolute) comes from palm oil (both from Indonesia and Malaysia) and soybean (Argentina). The use of rapeseed for biodiesel is in absolute terms similar to the values from 2016, with the increases mainly caused by biodiesel produced from palm oil, soybean and UCO.

Table 8. Origin of feedstock for biodiesel as consumed within the EU (2018, % and ktoe). Source: Navigant analysis

	Rapeseed	Palm oil	Soybean	UCO	Animal fat	Other, pine/tall oils, fatty acids, sunflower oil	Total (%)	Total (ktoe)
EU	26%		1%	8%	5%	1%	41%	**5,871**
Australia	2%						2%	**308**
Ukraine	2%						3%	**362**
Canada							1%	**96**
Indonesia		15%		2%			17%	**2,382**
Malaysia		7%		1%			8%	**1,082**
USA			3%	1%			4%	**580**
Brazil			2%				2%	**266**
China				4%			4%	**527**
Argentina			9%				9%	**1,342**
Other		1%2)		3%3)		1%	5%	**707**
Unknown	1%1)					4%	5%	**671**
Total (%)	32%	23%	15%	19%	5%	6%	100%	
Total (ktoe)	**4,502**	**3,208**	**2,193**	**2,678**	**693**	**921**		**14,194**

1) Small fraction of rapeseed imports is reported in the Eurostat [EU trade since 1988 by CN8 [DS-016890]] as import from countries and territories not specified for commercial or military reasons
2) Smaller fractions of palm oil-based biodiesel are estimated to originate from amongst others Honduras (0.3%), Guatemala (0.1%) and Colombia (0.1%)
3) Smaller fractions of UCO biodiesel are estimated to originate from amongst others Saudi Arabia (0.5%), Japan (0.3%), Russia (0.3%)

Table 9 shows the origin of feedstock used for EU bioethanol consumption in 2018. About 73% of the bioethanol consumed in the EU in 2018 is estimated to stem from feedstocks produced in the EU, mainly wheat (34%), maize (24%) and sugar beet (14%) and only a small amount (0.3%) from

[135] Investigations into suspected fraud cases regarding UCO are currently ongoing (Transport & Environment 2020, Letter from the Dutch Ministry of Infrastructure and Water Management to the The President of the House of Representatives of the States General, June 2020). Outcomes of this assessment are solely based on statistics.
[136] Ecofys, A Navigant company, 2019, Technical assistance in realisation of the 2018 report on biofuels sustainability Biofuels, biomass & biogas used for renewable energy generation:
https://ec.europa.eu/energy/sites/ener/files/documents/technical_assistance_in_realisation_of_the_2018_report_on_biomass_sustainability-final_report.pdf

cellulosic ethanol. In reality, this number is possibly higher, as the origin of barley, rye and triticale was not assessed, but can be expected to originate partially from the EU. Non-EU origin feedstocks account for about 27% of the EU bioethanol market, mainly maize originating from Ukraine, USA, Pakistan, Russia, Brazil and Canada.

In comparison, in 2016[137] similar analysis indicated that 65% of the bioethanol was based on EU feedstocks. Also, in absolute terms (2,199 ktoe in 2018 versus 1,700 in 2016), the share of the EU feedstocks increased. The main increase in share (both percentage as well as absolute) comes from European wheat-based ethanol. This is now also the largest feedstock used for ethanol, while in 2016 this was maize (whose share in absolute terms remained stable).

Table 9. Origin of feedstock for bioethanol as consumed within the EU (2018, % and ktoe). Source: Navigant analysis

	Wheat	Maize	Barley	Rye	Triticale	Sugar beet	Sugar cane	Cellulosic	Unknown/ other	Total (%)	Total (ktoe)
EU	34%	24%				14%		0%		73%	2,199
Ukraine	0%	4%							0%	4.5%	134
Brazil		2%					1%			2.6%	79
Canada	0%	1%								0.8%	24
USA	0%	2%								2.2%	68
Russia	1%	0%								1.6%	50
Pakistan							2%			1.6%	49
Other	0%	1%					1%		2%	4.0%	119
Unknown			2%	3%	5%					9%	285
Total (%)	37%	34%	2%	3%	5%	14%	4%	0%	2%	100%	
Total (ktoe)	**1,101**	**1,016**	**70**	**79**	**136**	**425**	**116**	**8**	**54**		**3,006**

4.4.2 Global biofuels trade

Figure 24 shows the global biodiesel trade in 2018. In 2018, a total of 24,805 ktonne of biodiesel was imported by EU countries, of which 13% (3,259 ktonne) was imported from countries outside the EU. The most notable observation from this figure is the return of import flows from Indonesia and Argentina. In 2011 and 2012, Indonesia and Argentina were the major exporters of biodiesel to the EU, with a combined export volume of more than 2,500 ktonne per year (>88% of the total import to the EU). After enforcement of the EC anti-dumping tariffs on biodiesel imports from Argentina and Indonesia, the biodiesel imports from these two countries dropped significantly since 2013 (combined volume of 820 ktonne in 2013 and 430 ktonne in 2014) and almost ceased in 2015 and 2016.

Since then the void was partially filled with domestic EU production and with an increase of imports from countries not impacted by the EC anti-dumping tariffs such as Brazil, China, India, Malaysia and South Korea. In 2018, Argentina and Indonesia regained their positions as major exporters of biodiesel to the EU, with exports from 1,648 ktonne and 785 ktonne respectively. This was due to the removal of anti-dumping duties from Argentina in September 2017 and Indonesia in March 2018.[138]

Next to that, trade within the EU increased significantly from 8,734 ktonne in 2016 to 21,545 ktonne in 2018[139]. Also, exports to the USA increased to 575 ktonne in 2018. In 2016, the USA mainly imported

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[137] Ecofys, A Navigant company, 2019, Technical assistance in realisation of the 2018 report on biofuels sustainability Biofuels, biomass & biogas used for renewable energy generation: https://ec.europa.eu/energy/sites/ener/files/documents/technical_assistance_in_realisation_of_the_2018_report_on_biomass_sustainability-final_report.pdf

[138] USDA GAINS Report, *EU Biofuels Annual 2019.*

[139] Please note that we have not been able to identify the reason behind this quite drastic increase. It could just be regular trade fluctuations, but no specific reason in the market has been identified so far. The import from outside the EU has increased a lot (from 467 ktonne in 2016 to 3159 ktonne in 2018), which probably enters through a limited number of major ports/entry points and then gets distributed to other EU countries. It could be that the increased import from outside the EU is thus the main reason for increased inter-EU trade.

from Argentina and the Pacific region, while in 2018 the highest share of biodiesel import was from the EU. This is most likely linked to the increase of export tax on biodiesel from 8 to 15% in Argentina, effective as of July 2018.[140]

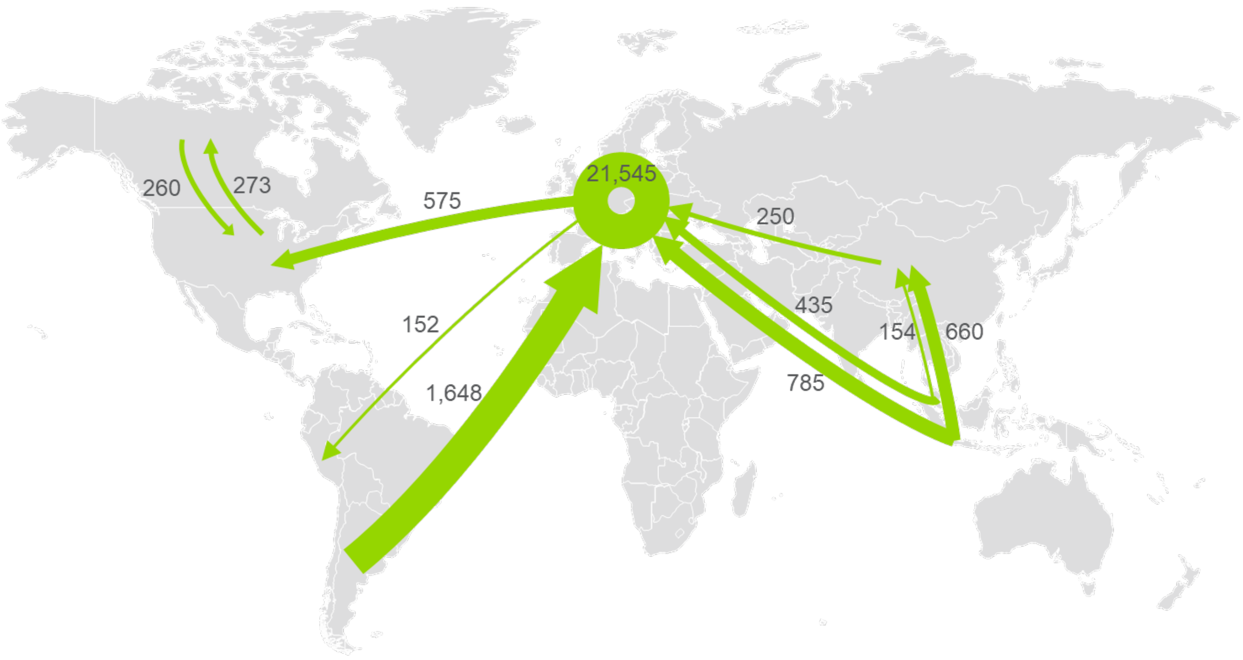

Figure 24. Global biodiesel trade (2018, ktonne).[141] Source: Eurostat, Comtrade

Figure 25 shows the global ethanol trade in 2018. In 2018, a total of 5,238 ktonne of ethanol was imported by EU countries, of which 9.5% (497 ktonne) was imported from countries outside the EU. The main suppliers were Pakistan (100 ktonne), the USA (91 ktonne), Russia (73 ktonne), Guatemala (67 ktonne) and Brazil (58 ktonne). Although Pakistan and Guatemala are not large bioethanol producers from a global perspective, the EU has zero duty trade relationships with both countries which makes for a favourable import setting.[142]

The EU ethanol import landscape has seen important changes since 2012. In 2012, imports accounted for 21% of the EU ethanol market, half of which was imported from the USA because of low EU import duties for high ethanol blends combined with the Volumetric Ethanol Excise Tax Credit (VEETC) in the USA. This resulted in the dumping of USA bioethanol in the EU market which subsequently reduced the market share of domestically produced bioethanol. As of February 2013, the EC imposed a five-year anti-dumping tariff of €49.20 per 1,000 litres in addition to the already imposed import tariff of €102 per 1,000 litres on the bioethanol import from the US. This rate significantly cut USA exports of ethanol to the EU from 522 ktonne in 2012 to 91 ktonne in 2018.

EU ethanol export to destinations outside of the EU was marginal, at only 107 ktonne in 2018.

The USA and Brazil were the largest global exporters of ethanol in 2018, and collectively exported more than 9,000 ktonne of ethanol. Aside from intra-trade between the two nations and export to Canada from the USA, the majority of the USA and Brazil ethanol found its way to the Asian market, mainly in India (867 ktonne from the USA and 9 ktonne from Brazil), South Korea (432 ktonne from Brazil and 328 ktonne from the USA), Japan (430 ktonne from Brazil and 110 ktonne from the USA),

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[140] USDA GAINS Report, *EU Biofuels Annual 2018.*
[141] Trade flows larger than 100 ktonne are shown. Trade based on codes 38260010 and 38260090 (Biodiesel and mixtures thereof, not containing or containing less than 70% by weight of petroleum oils or oils obtained from bituminous minerals) including both FAME biodiesel and other biodiesel such as HVO.
[142] USDA GAINS Report, *EU Biofuels Annual 2019.*

Philippines (464 ktonne from the USA and 7 ktonne from Brazil), and China (464 ktonne from the USA). In 2016, the combined export of the USA and Brazil was just above 3,200 ktonne of ethanol and these countries have significantly scaled up their export since then.

It can be concluded that the international biofuel market is quite dynamic and trade routes change continuously. The production side is volatile in particular because of weather impacts and the influences from other agricultural commodity markets. Changes in international biofuels policy and trade barriers such as import tariffs are other important factors that influence the international biofuel market.

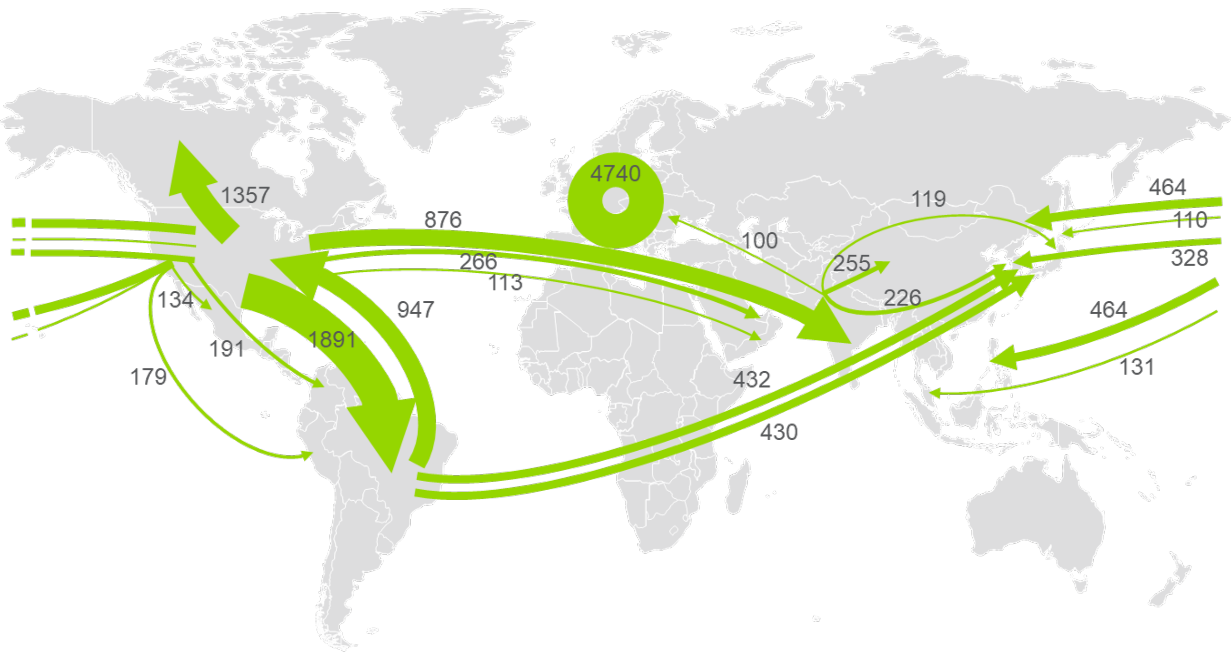


Figure 25. Global ethanol trade (2018, ktonne). [143] **Source: Eurostat, Comtrade**

[143] Trade flows larger than 100 ktonne are shown. Trade based on codes 22072000 (Ethyl alcohol and other spirits, denatured, of any strength) and 2207100 (Undenatured ethyl alcohol of an alcoholic strength by volume of 80% vol or higher).

5. Environmental impacts related to biofuels

The Renewable Energy Directive requires Member States and the European Commission to report on various local and global sustainability aspects of biofuels consumed in the national markets and in the EU as a whole. This includes both environmental aspects (this chapter) and socio-economic aspects (Chapter 6). Environmental impacts related to biofuels consumed in the EU are assessed on the basis of the Member State Progress Reports and additional analysis of literature and statistics. All Member States have implemented measures to safeguard sustainability criteria in line with the criteria set out in the Directive.

The land use, around the world, for biofuels consumed in the EU has been estimated on the basis of the breakdown of biofuels volume from crops and countries of origin presented in Chapter 4. Overall, it is estimated that7.4 Mha of cropland globally (close to the total land area of Ireland), of which 3.4 Mha in the EU (comparable to the total land area of the Netherlands), has been used for the production of crops for EU biofuel consumption. Member States have also reported on crop area for biofuels feedstock, but they often report on the whole crop area, without specifying the (small) part used for the biofuel feedstocks. Member States also do not cover the impact in third countries related to imported feedstocks.

On the basis of the crop-fuel volumes estimated in the previous chapter, the total greenhouse gas emission reduction from EU consumed biofuels in 2018 is estimated to be 48.6 Mtonne CO_{2eq}, which is comparable to the annual emissions of 10.5 million cars. In their Progress Reports, Member States report a total emission reduction of 45.6 Mtonne CO_{2eq} (uncertain if this includes or excludes ILUC values).

When the 2018 crop feedstock volumes are multiplied by the corresponding mean ILUC values from the ILUC Directive, the total emission savings from renewable energy in transport is reduced to 24.0 Mtonne of CO_2 savings (within a range of 18.8-33.8 Mtonne of CO_2 savings).

In recent years, several new studies on ILUC have been published (see review in Section 5.3.1). They confirm the understanding that the ILUC impact depends on many factors. Gradually, less research is focusing on quantification of ILUC, while more studies focus on ILUC mitigation.

Feedstock production for all types of EU consumed biofuels can have local environmental impacts. These impacts are site specific and depend on the agricultural practices applied on that specific farm or region. Voluntary schemes help to ensure that biofuels are sustainably produced and comply with the EU sustainability criteria. Several schemes, recognised by the EC, also consider additional sustainability aspects such as soil, water, air protection and social criteria. However, this may not completely avoid impacts, and a continued effort is needed to decrease impact and increase insights in the size of these impacts.

The majority of countries (Member States and main third countries) have ratified all relevant conventions on biodiversity and labour. Malaysia has accepted/ratified the majority of the relevant conventions. The USA, however, has ratified or accepted only two of the relevant conventions. Globally, there have been very limited changes in ratification and acceptance of conventions by the countries relevant for EU biofuel feedstock production since 2010. Thus, although coverage is reasonable over the amount of countries providing feedstock, very little improvements can be shown since 2010, as discussed in Section 5.5.

5.1 Measures taken to respect the sustainability criteria for biofuels

National implementation of Renewable Energy Directive sustainability criteria and the ILUC Directive are presented in Table 10. All of the 28 Member States have implemented the Renewable Energy Directive's sustainability criteria in their national legislation.

Fourteen Member States reported that they have implemented the ILUC Directive already in national legislation (see Table 10). One Member State, Bulgaria, mentions that the implementation of the ILUC Directive has started in 2018. The other thirteen Member States have not mentioned the ILUC Directive, or its national implementation, in their Progress Reports. They have however reported to the Commission that the ILUC Directive has been implemented.

Table 10. National implementation measures to respect biofuel sustainability criteria. Source: MS Progress Reports and communication by EC

Member State	National implementation of RED sustainability criteria	National implementation of ILUC Directive
Austria	Yes	Reported as 'existing' amendment
Belgium	Yes	Implemented 2019
Bulgaria	Yes	Started implementing into national law in 2018
Croatia	Yes[144]	Reported to EC as implemented
Cyprus	Yes	Reported to EC as implemented
Czech Republic	Yes	Reported to EC as implemented
Denmark	Yes	Reported to EC as implemented
Estonia	Yes	Reported to EC as implemented
Finland	Yes	Implemented July 2017
France	Yes	Reported to EC as implemented
Germany	Yes	Implemented 2017
Greece	Yes	Implemented 2018
Hungary	Yes	Reported to EC as implemented
Ireland	Yes	Implemented 2016
Italy	Yes	Implemented March 2017
Latvia	Yes	Reported to EC as implemented
Lithuania	Yes	Implemented July 2017
Luxembourg	Yes	Implemented 2017
Malta	Yes	Reported to EC as implemented
Netherlands	Yes	Implemented 2018
Poland	Yes	Implemented January 2018
Portugal	Yes	Reported to EC as implemented
Romania	Yes	Implemented 2015
Slovakia	Yes	Reported to EC as implemented
Slovenia	Yes	Reported to EC as implemented
Spain	Yes	Implemented 2018
Sweden	Yes	Implemented
UK	Yes	Reported to EC as implemented

[144] Please note that national implementation of the Renewable Energy Directive has not been explicitly mentioned in the Progress Report. However, obligations and related biofuel quotas are set through the Biofuel Action Plan, which therefore seems to cover the implementation of the Directive.

5.2 Land use and land use changes

This section analysis the changes in land use associated to the production of EU biofuels consumption, on the basis of the following two types of data sources:

1. A statistical analysis: The total amount of land that is used to produce the feedstocks is calculated by combining the results about the type and origins of feedstocks, with associated yields per country of origin. This also gives insights into land use for EU biofuel consumption in the main countries of supply.
2. The data reported in the Member State Progress Reports.

5.2.1 Statistical analysis

Most of the feedstocks for biofuels consumed in the EU originate from food/feed crops such as sugar, starch or vegetable oil crops. Therefore, it is important to understand how biofuel consumption in the EU impacts the land used for this part of food/feed crop production both domestically and globally. In this section the total land use for the production of biodiesel and bioethanol, as the main fuel additives/replacement to diesel and gasoline, in the EU transport sector in 2018 is estimated based on statistical analysis. This estimate covers, separately, lands that are used within the EU and in third countries, for the production of biofuels consumed in the EU.

To model the land use, this report applies a methodology[145] based on combining the origin of feedstocks for biofuels production (as developed in Section 4.4) with country specific crop yields. Co-products were accounted for by means of energy allocation in line with the greenhouse gas accounting rules of the Renewable Energy Directive.[146] The method does not deliver an exact insight into where feedstock for EU biofuels has been originally produced, because there are many unknowns in the supply chain. However, it can estimate land use, based on market averages, insights into the trade of main biofuels and main feedstock.

[145] This methodology is based on the methodology as developed by Ecofys for the use in the Ecofys report for the European Commission on renewable energy progress and biofuels sustainability, published in November 2014.

[146] This means that only part of the land used to grow a crop is really for the main product, as another part can be allocated to the co-product. Therefore, the amount of land that is really needed for a biofuel is less than what would be expected if one would multiply the crop yield with conversion efficiencies.

Methodology for land use modelling

The land use for crops used as feedstock for biodiesel and bioethanol is modelled based on the types and origin of feedstock, as assessed in Section 4.4.1. Land use is assessed for the most relevant crop-country combinations:

- Land use for rapeseed, wheat, maize and sugar beet in the EU
- Land use for soybeans in Argentina
- Land use for oil palm fruit in Malaysia and Indonesia

As reference, we indicate the breakdown of all land in these countries, based on the FAO database:

- Non-agricultural land
- Meadows and Pastures
- Land use for the assessed crops and all other crops

The land used for the biofuel production for a specific crop-country combination is estimated based on:

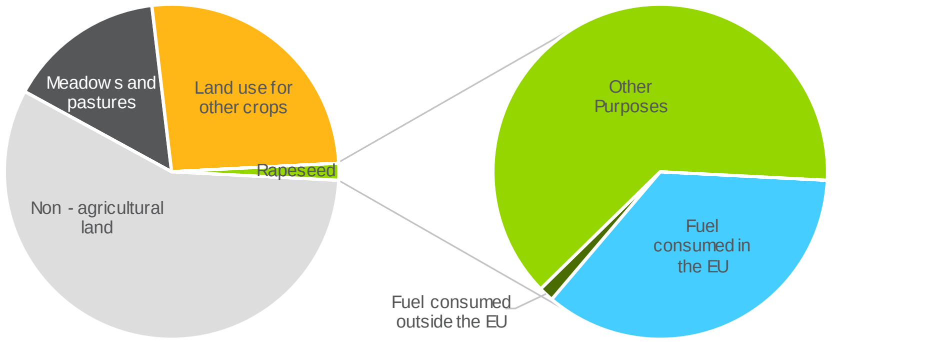
- The total biofuel production of that country
- Export of biofuel from that country to the EU
- The share of the assessed crop as feedstock for biofuel production in the assessed country
- The conversion factor of the assessed crop to biodiesel
- The crop yield per area of land for the assessed crop-country combination

Figure 26 shows how the land use for biofuel crops relates to other agricultural land use and the total land area of the country, for a selection of the main crop/country combinations used for the production of EU consumed biofuels in 2018. It is expected that these figures are higher than the actual land area used for biofuel crops, because conservative data has been used for the conversion efficiencies and yields.[147]

Within the EU, 3.4 Mha of land is used for crops which are converted to biofuels in the EU and consumed within the EU. This equals 3% of the total cropland, which is 117 Mha in the EU. 0.1 Mha of land within the EU is used for crops which are converted to biofuels in the EU and exported to countries outside the EU. Rapeseed was the main crop used for biofuels production in the EU and represented 72% of the share of the total European land used for biofuels production.

[147] Efficiencies are taken from the BioGrace tool, which was developed to mimic the greenhouse gas performance as tabulated in the Renewable Energy Directive in 2009. It should be expected that supply chain efficiency has improved in the meantime. Yield data is taken from FAOstat, even though the most recent year is taken as reference, it is expected that part of the data is outdated. Moreover, it does not take into account options of multi-cropping and advantages following from crop rotation.

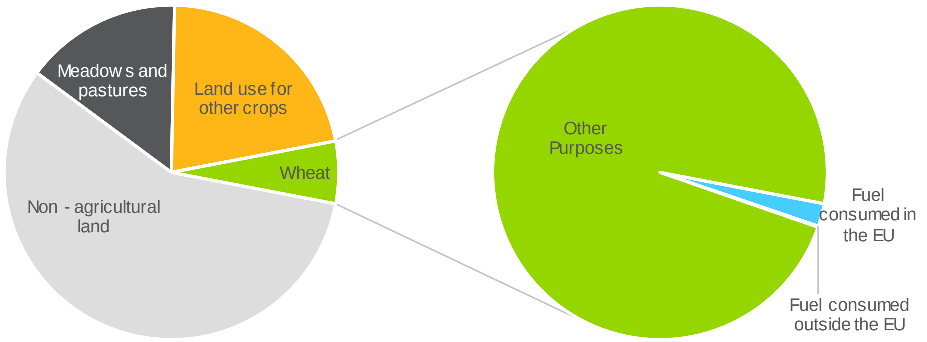
Land use for production of Rapeseed for Biodiesel in EU in 2018



Total land area	**423,796**	**kha**
Non - agricultural land	242,150	kha
Meadows and pastures	64,227	kha
Total land use for Rapeseed	6,891	kha
Land use for other crops	110,526	kha

Land for Rapeseed	**6,891**	**kha**
Rapeseed for Biodiesel produced in the EU - consumed in the EU	2,440	kha
Rapeseed for Biodiesel produced in the EU - consumed outside of the EU	100	kha
Rapeseed for other purposes	4,351	kha

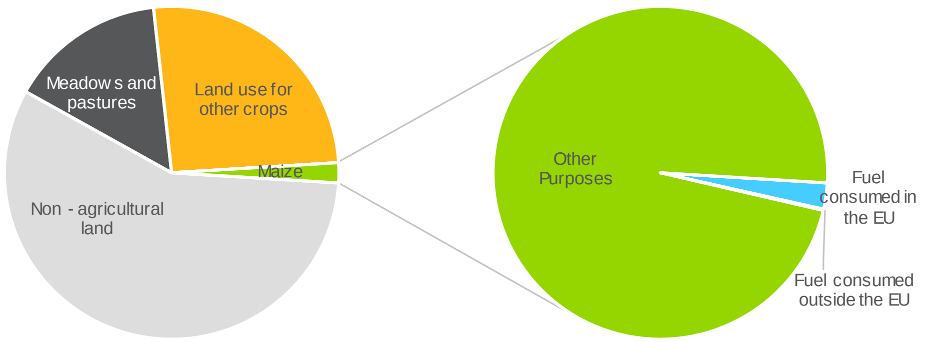
Land use for production of Wheat for Bioethanol in EU in 2018



Total land area	**423,796**	**kha**
Non - agricultural land	242,150	kha
Meadows and pastures	64,227	kha
Total land use for Wheat	25,496	kha
Land use for other crops	91,922	kha

Land for Wheat	**25,496**	**kha**
Wheat for Bioethanol produced in the EU - consumed in the EU	563	kha
Wheat for Bioethanol produced in the EU - consumed outside of the EU	26	kha
Wheat for other purposes	24,907	kha

Land use for production of Maize for Bioethanol in EU in 2018



Total land area	**423,796**	**kha**
Non - agricultural land	242,150	kha
Meadows and pastures	64,227	kha
Total land use for Maize	8,246	kha
Land use for other crops	109,171	kha

Land for Maize	**8,246**	**kha**
Maize for Bioethanol produced in the EU - consumed in the EU	210	kha
Maize for Bioethanol produced in the EU - consumed outside of the EU	10	kha
Maize for other purposes	8,027	kha

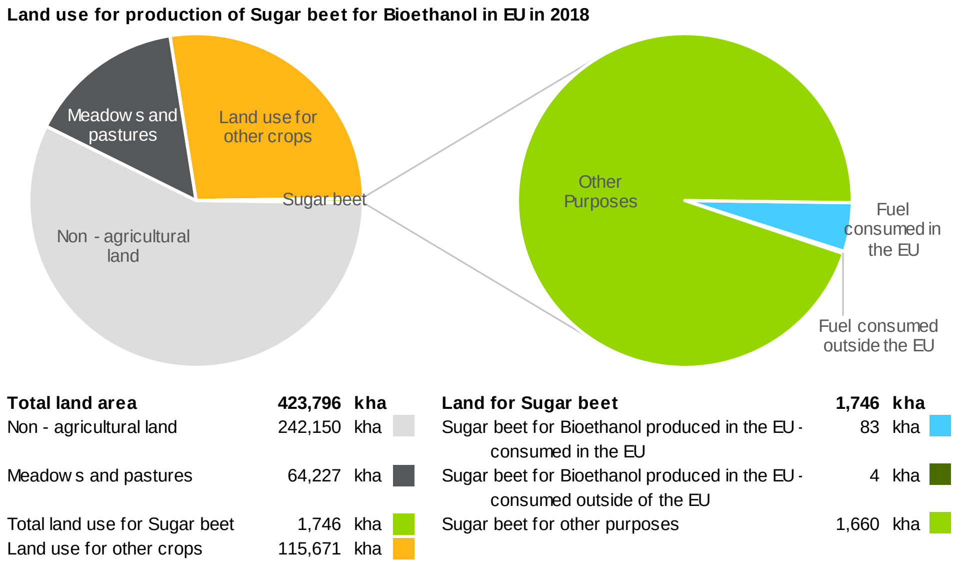


Figure 26. Land use for production dedicated to EU biofuel production versus other land uses, for major crops in the EU (2018). Source: Navigant analysis

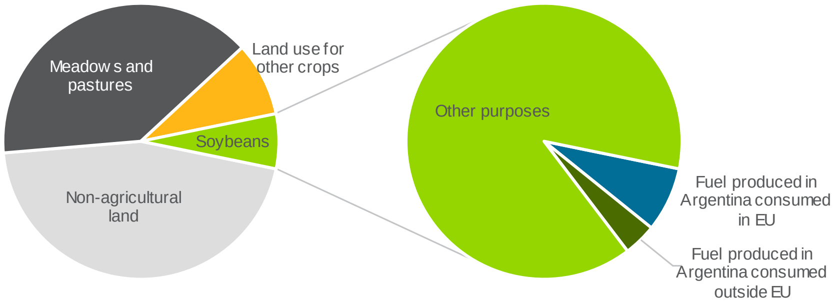
Out of the 7.4 Mha land used for biofuels feedstock in 2018, 3.4 Mha (46%) is located within the EU and 3.8 Mha (51%) is located outside the EU.[148] For the main feedstock supplying countries outside the EU (see Figure 27), the share of cropland that was estimated to be used for feedstock for EU biofuels is likely small. For Indonesia it is estimated that less than 1% of their total cropland was used for the extraction of feedstocks that were used in the production of biofuels produced or consumed in the EU. For Argentina (for soybean production for biofuels produced or consumed in the EU) and Malaysia (for palm oil for biofuels consumed or produced in the EU) the share of land estimated to be used for feedstock for EU biofuels makes up 3.3% of the total cropland. As shown in Section 4.4.2, Argentina is the largest exporter of biodiesel to the EU in 2018.

Indonesia was estimated to use 9.8% of its palm oil cultivated land for biofuels that were produced or consumed in the EU in 2018. This is higher than in 2016 (5.2%) and 2012 (6.5%).[149] The drop from 2012 to 2016 is likely to be a result of the combination of the considerable increase in total land used for palm oil cultivation and the implementation of the EC anti-dumping tariffs on biodiesel imports from Indonesia since 2013 (please refer to Section 4.4 for details). This did not impact the import of palm oil and EU producers could still use imported palm oil. The increase observed from 2016 to 2018 is likely driven by the increase of palm-oil export from Indonesia to the EU after the removal of anti-dumping duties from Indonesia in March 2018.[150] As shown in Figure 27, the majority of land used for palm oil production (95%) is used for production of palm oil for other purposes than biodiesel production. Around half of all palm oil exported by Indonesia is exported to India (23%), China (13%), Pakistan (9%) and Bangladesh (5%). Palm oil use in these countries includes consumption in the food market.[151]

Malaysia, the third largest biodiesel exporter to the EU in 2016, used 1.2% of its total palm oil cultivated land for biofuels that were produced or consumed in the EU.

[148] The remaining 0.2 Mha (3%) of feedstock concerns barley, rye and triticale sourced from unknown countries.
[149] Values for 2016 and 2012 were estimated based on a similar analysis based on FAO data for those years.
[150] USDA GAINS Report, *EU Biofuels Annual 2019.*
[151] UN Comtrade Database

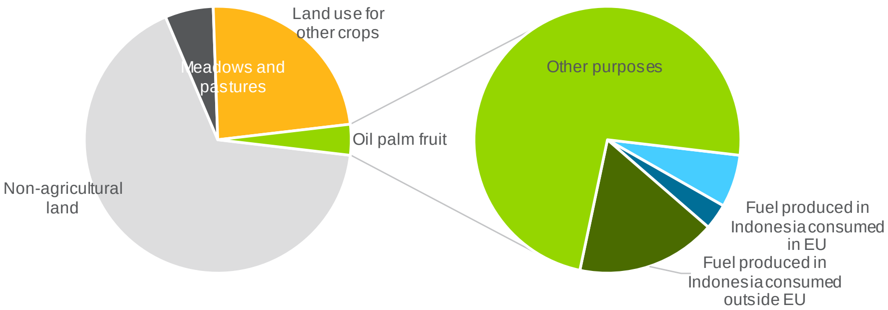
Land use for production of Soybeans for Biodiesel in Argentina in 2018



Total land area	**273,669**	**kha**
Non - agricultural land	124,969	kha
Meadow s and pastures	108,500	kha
Total land use for Soybeans	16,318	kha
Land use for other crops	23,882	kha

Land for Soybeans	**16,318**	**kha**
Soybeans for Biodiesel produced in the EU	0	kha
Soybeans for Biodiesel produced in Argentina - consumed in the EU	1,340	kha
Soybeans for Biodiesel produced in Argentina - consumed outside of the EU	680	kha
Soybeans for other purposes	15,638	kha

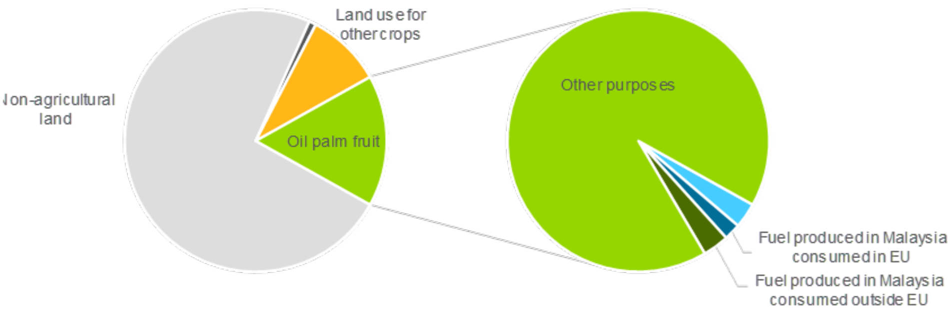
Land use for production of Oil palm fruit for Biodiesel in Indonesia in 2018



Total land area	**187,752**	**kha**
Non - agricultural land	125,452	kha
Meadows and pastures	11,000	kha
Total land use for Oil palm fruit	6,777	kha
Land use for other crops	44,523	kha

Land for Oil palm fruit	**6,777**	**kha**
Oil palm fruit for Biodiesel produced in the EU	446	kha
Oil palm fruit for Biodiesel produced in Indonesia - consumed in the EU	219	kha
Oil palm fruit for Biodiesel produced in Indonesia - consumed outside of the EU	1,186	kha
Oil palm fruit for other purposes	5,146	kha

Land use for production of Oil palm fruit for Biodiesel in Malaysia in 2018



Total land area	**32,855**	**kha**
Non - agricultural land	24,265	kha
Meadows and pastures	285	kha
Total land use for Oil palm fruit	5,236	kha
Land use for other crops	3,070	kha

Land for Oil palm fruit	**5,236**	**kha**
Oil palm fruit for Biodiesel produced in the EU	168	kha
Oil palm fruit for Biodiesel produced in Malaysia - consumed in the EU	110	kha
Oil palm fruit for Biodiesel produced in Malaysia - consumed outside of the EU	173	kha
Oil palm fruit for other purposes	4,895	kha

Figure 27. Land use for crop production dedicated to EU biofuels versus other land uses, for major crop-country combinations (2018). Source: Navigant analysis

To put the global land use for crops used for biofuels consumed in Europe in perspective, the following table shows the land use for biofuels consumed in Europe as percentage of total land used for the production of that crop.

Table 11. Land use for crops used for biofuels consumed in the EU in comparison to global land use for production of those crops in 2018. Source: FAOstat and Navigant analysis

Crops	Land for biofuels consumed in EU (kha)	Global land used for crop production (kha)	Share of global land use (%)
Rapeseed	3,201	37,580	8.5%
Palm oil	981	18,917	5.2%
Soybean	1,908	124,922	1.5%
Wheat	652	214,292	0.3%
Maize	309	194,904	0.2%
Sugar beet	84	4,809	1.8%
Sugar cane	44	26,270	0.2%
Other (barley, rye, triticale)	245	55,855	0.4%
Land for EU biofuels crops compared to global total cropland	**7,424**	1,423,329	0.5%

5.2.2 Member States reported land use for production of crops for energy use

Member States are required to every two years report any changes in land use associated with the increased use of biomass or other sources of renewable energy in their Progress Reports[152].

At the time of writing this report, all 28 Member States submitted their 2019 Progress Reports to the Commission. Of these, ten Member States (Croatia, Cyprus, Estonia, Finland, France, Malta, Slovenia, Spain, Sweden and the UK) did not report land used for crops dedicated to bioenergy. The other Member States reported land use in the following three general categories:

- Land used for common arable crops (including starch, sugar and oilseeds)
- Land used for short rotation trees
- Land used for other energy crops such as grasses

Please note that the land use reported by Member States covers crop production dedicated to total bioenergy use including solid, gaseous and liquid biofuels that are consumed in the electricity, heating & cooling and transport sectors combined. The method for reporting land use differs per Member State and sometimes concerns all land used for a crop, not limited to the share used for bioenergy production.

Most Member States reported limited, or no impact, on land use within their territory (Austria, Denmark, Bulgaria, Hungary, the Netherlands, Poland, Spain and Sweden). These Member States refer to land use statistics to support the conclusion that increased use of biomass and renewable energy has limited impact on land use in their Member State. Other Member States (Belgium, Cyprus, the Czechia, Estonia, Finland, Lithuania, Norway and Portugal) estimate the impact without providing further quantitative evidence or clarifications on the methodology applied. However, in general, the data quality is poor: definitions vary per Member State, and different methods have been used for data collection. Twelve Member States report data on land used for energy crops with the by largest amounts in Italy. Some only report the data for a certain land use type but not for others (e.g. Bulgaria, Greece and Lithuania). One Member State, Slovakia, reported the total crop land and showed the share of crops dedicated to bioenergy.

In some of the Progress Reports, it is not clear whether the data represent total cropland or only cropland dedicated to bioenergy (e.g. this is the case for Bulgaria, Greece, Ireland, Italy and Latvia). It is therefore difficult to draw any overall conclusions based on the data provided. This is also shown when the total area reported by Member States (17 Mha) is compared to the calculated amount of

[152] Available at https://ec.europa.eu/energy/en/topics/renewable-energy/progress-reports

land required in Europe to produce the total amount of biofuels consumed in the EU in 2018 (3.4 Mha, see previous section on statistical analysis).

Table 12 shows the amount of land used in the EU for the production of crops used for bioenergy purposes, as reported in the Member States Progress Reports. As can be seen from the table, the overall growth of land use over the period 2017-2018 has been negative. Both the land used for short rotation trees as well as the land used for other energy crops reduced substantially (by 7.2% and 5.7%), which occurred mainly in Finland, Latvia, the Netherlands, Slovakia, Belgium and Poland. The land used for the cultivation of common arable crops and oilseeds shows significant expansion in some Member States (Belgium 49%, Luxembourg 41%, Hungary 11%, Slovakia and Poland 9%, Lithuania 8%, the Netherlands 8%) with an overall reduction of about 1% across the EU between 2017 and 2018. A slight decrease can be seen in the period from 2015-2018. This is mainly due to land use reductions in Bulgaria, Denmark, Germany, Ireland, Italy and Poland and due to France not reporting on land use in 2017 and 2018. Yet, over 99% of the reported land in 2018 is land used for the cultivation of common arable crops and oilseeds.

Again, note that in some of the Progress Reports, it is not clear whether the data represents total crop land or only crop land dedicated to bioenergy. This makes it difficult to draw conclusions on the significant expansion noted (which could also relate to overall crop production, price developments or surpluses in other markets etc.). The largest amounts of land reported in relation to bioenergy production are found in Romania (37%), Italy (20%), Bulgaria (13%) and Germany (12%) in 2018 (as a percentage of the total reported land by all Member States).

Table 12. Land use for crops dedicated to energy production (ha) – common arable crops and oilseeds. Source: MS Progress Reports

	Common arable crops and oilseeds						
Member State	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Austria	67,300	77,500	71,500	38,100	51,400	52,200	45,500
Belgium	16,674	23,453	20,634	-	-	4,816	7,197
Bulgaria	-	-	-	2,886,137	2,864,916	2,223,342	2,193,323
Croatia	-	-	-	0	0	0	0
Cyprus	-	-	-	0	0	0	0
Czechia	172,426	159,745	164,463	159,797	134,551	159,904	123,662
Denmark	70,000	130,000	125,000	150,000	130,000	140,000	120,000
Estonia	-	-	-	-	-	0	0
Finland	n/a	n/a	n/a	0	0	n/a	n/a
France	1,230,073	-	1,162,799	1,375,450	1,158,600	-	-
Germany	2,147,400	1,979,700	2,211,300	2,431,800	2,396,700	2,163,600	2,149,300
Greece	67,389	78,460	80,491	102,545	77,483	86,009	86,059
Hungary	197,000	300,000	300,000	0	0	245,751	272,307
Ireland	315,000	320,599	318,042	311,787	299,453	292,529	288,494
Italy	-	-	-	3,665,076	3,677,980	3,558,622	3,436,075
Latvia	693,424	549,500	556,600	574,600	620,300	628,298	569,834
Lithuania	177,320	-	-	137,000	139,000	165,000	178,000
Luxembourg	581	531	591	932	848	720	1,014
Malta	-	-	-	-	-	0	0
Netherlands	4,000	800	800	3,000	2,300	2,400	2,600
Poland	n/a	601,370	553,975	2,612,581	2,560,021	848	925
Portugal	4,357	-	-	1,287	1,797	336,637	302,049
Romania	6,125	6,176,900	6,248,300	6,248,700	6,396,500	6,218,800	6,365,000
Slovakia	153,000	220,683	187,914	127,308	117,946	134,028	145,521
Slovenia	5,141	6,131	5,563	1,629	3,156	-[1]	-[1]
Spain	n/a	-	-	-	-	-[2]	-[2]
Sweden	n/a	n/a	n/a	0	0	n/a	n/a
UK	14,942	42,000	112,000	5,885	5,911	-	-
EU-28	5,342,152	10,667,372	12,119,972	20,833,613	20,638,862	17,260,556[3]	17,210,635[3]

1) The Slovenian member state Progress Report only provides the statement that there was no domestic production of biofuels in Slovenia.
2) The member state Progress Report of Spain indicates that data on land use for crops dedicated to energy production is not available, but states that feedstock for biodiesel, HVO and bioethanol is grown in Spain for respectively 0.35%, 0.0% and 15.81%.
3) Assuming numbers for Poland are 1.000 times larger than reported. The Polish Member State Progress Report, reported numbers in ha for 2017-2018. Comparing their numbers to historical values and values of other countries it seems likely that these numbers were actually in kha.

Table 13. Land use for crops dedicated to energy production (ha) – short rotation trees and other energy crops. Source: MS Progress Reports

	Short rotation trees							Other energy crops						
Member State	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Austria	1,500	1,500	1,500	1,240	1,221	1,221	1,195	1,214	1,179	1,173	1,075	1,078	1,125	1,071
Belgium	165	100	91	-	-	122	122	138	43	47	-	-	509	408
Bulgaria	-	1584	1595	0	0	-	-	n/a	-	-	6,821	3,286	-	-
Croatia	-	-	-	0	0	0	0	-	-	-	0	0	0	0
Cyprus	-	-	-	-	-	0	0	-	-	-	-	-	0	0
Czechia	1,292	1,589	2,086	2,838	2,869	2,850	2,738	n/a	n/a	n/a	0	0	-	-
Denmark	4,000	9,014	9,518	9,088	8,896	8,780	8,651	50	85	80	78	66	78	86
Estonia	-	-	-	-	-	0	0	-	-	-	-	-	0	0
Finland	36	42	24	23	26	34	29	14,949	8,549	7,501	5,776	5,452	965	829
France	4,508	4,062	5,539	0	0	-	-	n/a	-	-	0	0	-	-
Germany	4,900	6,000	6,000	6,600	6,600	6,630	6,630	2,000	3,200	4,900	4,900	5,400	6,400	7,600
Greece	-	-	-	0	0	-	-	-	-	-	0	72	-	-
Hungary	n/a	n/a	n/a	4,082	4,104	4,104	4,104	n/a	n/a	n/a	0	0	n/a	n/a
Ireland	839	914	1,033	1,052	1,046	830	843	2,349	2,055	1,612	1,285	1,100	973	863
Italy	6000	5000	5000	0	0	-	-	n/a	-	-	0	0	40,901	39,596
Latvia	321	6,628	-	0	0	810	700	884	-	-	0	0	258	252
Lithuania	2,000	-	-	3,436	4,063	-	-	n/a	-	-	0	0	-	-
Luxembourg	n/a	n/a	n/a	0	0	n/a	n/a	84	187	92	215	211	244	295
Malta	-	-	-	-	-	0	0	-	-	-	-	-	0	0
Netherlands	6	7	20	33	13	14	8	124	191	190	280	245	242	262
Poland	10344	11,486	13,499	276	804	22	20	n/a	-	-	18,406	10,000	11	8
Portugal	n/a	-	-	0	0	n/a	n/a	n/a	-	-	0	0	n/a	n/a
Romania	n/a	n/a	n/a	300	3,200	4,600	4,420	0	0	0	0	1,200	970	1,040
Slovakia	n/a	590	650	0	0	1,020	145	n/a	-	-	0	0	-	-
Slovenia	n/a	-	-	0	0	-	-	n/a	-	-	0	0	-	-
Spain	n/a	-	-	-	-	-	-	n/a	-	-	-	-	-	-
Sweden	11861	11825	11637	11102	10193	10,246	9,389	912	906	646	661	669	643	691
UK	2,551	3,000	3,000	10	10	-	-	8,075	7,000	7,000	11,046	11,222	-	-
EU-28	50,323	63,341	61,192	40,080	43,045	63,652[1]	59,074[1]	30,779	23,395	23,241	50,543	40,001	64,708[1]	60,993[1]

1) Assuming numbers for Poland are 1.000 times larger than reported. The Polish Member State Progress Report, reported numbers in ha for 2017-2018. Comparing their numbers to historical values and values of other countries it seems likely that these numbers were actually in kha.

5.3 Greenhouse gas emission savings

Since biofuels account for 89% of the renewables used in transport (without the multipliers of the total renewable energy in transport), the assessment of greenhouse gas performance related to renewable energy in transport focuses on understanding the greenhouse gas performance of biofuels. First, the greenhouse gas emission reductions estimated by Member States are reported as they are included in their Progress Reports[153]. Second, the total savings are calculated from combining insights into the biofuel consumption and origin with reported savings.

The EU Member States reported on the greenhouse gas emissions savings resulting from the use of renewable energy in transport in their Progress Reports. At the time of writing, all 28 Member States submitted their Progress Reports. Of these, one Member State did not report on the greenhouse gas

[153] Available at https://ec.europa.eu/energy/en/topics/renewable-energy/progress-reports

emission savings (Belgium), and one other Member State (Estonia) only reported on greenhouse gas emissions savings per unit of fuel consumed. The reports indicate total greenhouse gas emission savings from transport and do not explain the roles of renewable electricity and (different types of) biofuels. However, given the overwhelming share of biofuels in the total amount of the renewables used in transport (89%), it can be expected that the emission savings largely result from the use of biofuels. In some Member States[154] a significant fraction is expected to come from the use of renewable electricity in transport, particularly in rail transport.

Table 14 presents the emission savings reported by the Member States. The reported savings indicate a total greenhouse gas emission savings of 45.6 Mtonne CO_{2eq} in 2018, which is a 14% increase in savings as compared to 2017. This is line with expectations as the share of renewable energy in the EU transport sector increased over the period of 2017-2018 (it was 7.1% in 2017 and 8.0% in 2018).[155] As mentioned, the emission savings in the transport sector are expected to be largely due to the use of biofuels. The amount of biofuels in EU transport increased by 12% between 2017 and 2018. In contrast to the 2015-2016 Progress Reports, in which Sweden was the only Member State reporting substantial year-on-year increases in emission savings, the 2017-2018 Progress Reports show many more Member States reporting substantial year-on-year increases in emission savings. These include Croatia (growing from 2 to 84ktCO_{2eq}), Latvia (203% growth), Slovenia (201% growth), the Netherlands (70% growth), Poland (46% growth), the UK (41% growth) and Hungary (36% growth). This could be attributed to the growth in biofuel consumption, as shown in Chapter 4.1.

None of the Member States indicate if the reported greenhouse gas emission savings include or exclude ILUC emissions. It is expected that Member States did not report ILUC emissions, since this was not required from the Member States for reporting in 2018. It is impossible to calculate the ILUC emissions per Member State, because this would require an exact insight in the feedstock composition per country, and in changing feedstock patterns over time: since ILUC occurs as a result of increasing feedstock consumption, the impact differs per time period.

[154] Countries with high share of renewable electricity in transport such as Austria (46%), Croatia (32%), Latvia (28%), Romania (25%). Share of renewable electricity in all renewable energy in transport, including multiplication factors. Source: SHARES database
[155] SHARES dataset, RES-T value including multiplicators.

Table 14. GHG emission savings from the use of RE in transport (ktonne CO_2eq). Source: MS Progress Reports

EU GHG savings (ktCO_2eq)		
Member States	**2017**	**2018**
Austria	1,600	1,600
Belgium	n/a	n/a
Bulgaria	229	272
Croatia	2	84
Cyprus	30	30
Czechia	887	876
Denmark	1	1
Estonia	n/a	n/a
Finland	760	720
France	7,600	7,600
Germany	7,400	7,700
Greece	331	336
Hungary	522	710
Ireland	473	471
Italy	3,000	3,400
Latvia	22	67
Lithuania	294	330
Luxembourg	331	360
Malta	23	29
Netherlands	874	1482
Poland	2,411	3,511
Portugal	819	944
Romania	1,165	1,246
Slovakia	338	366
Slovenia	74	223
Spain	3,403	4,318
Sweden	4,700	5,200
United Kingdom	2,639	3,726
EU	**39,927**	**45,600**

The greenhouse gas emission savings can also be estimated on the basis of the insights into biofuels feedstock and their origin (see Section 4.4) in combination with the greenhouse gas emissions for biofuel pathways (see Table 15).[156] This approach is limited to the greenhouse gas savings from the use of liquid biofuels (bioethanol and biodiesel) in transport and does not consider the savings related to the use of other types of renewable energy (gaseous biofuels and electricity). Therefore, the emission savings might be underestimated as in some Member States significant savings may come from use of renewable electricity in transport, especially in rail transport. In this exercise we use the information provided by the Commission

Without taking ILUC factors into account, a total greenhouse gas emission savings of 48.6 Mtonne CO_{2eq} (72% savings) was achieved through consuming 720,112 TJ of biofuels, compared to the situation where only fossil fuels would have been used.

[156] In previous progress reports, we have used the 'typical' greenhouse gas emissions from the Renewable Energy Directive for this analysis. In this edition, we have used the emissions for biofuels as reported by MS to the EEA. This information should be published by the EEA end of 2020.These emissions are a combination of actual emissions or typical default values as used by fuel suppliers to report to their MS.

Table 15. GHG savings related to EU biofuel consumption (2018). Source: Navigant analysis[157]

	Total consumption		ILUC factors not included			ILUC factors included (mean values)		
Fuel	**(ktoe)**	**(TJ)**	**GHG Emissions (gCO_2e/MJ)**	**GHG Savings (gCO_2e/MJ)**	**Total GHG Savings ($MtonneCO_2e$)**	**GHG Emissions (gCO_2e/MJ)**	**GHG Savings (gCO_2e/MJ)**	**Total GHG Savings ($MtonneCO_2e$)**
Biodiesel	14,194	594,275	26.7	67.3	40.0	65.6	28.4	16.9
Bioethanol	3,006	125,837	25.4	68.6	8.6	37.5	56.5	7.1
Total	**17,200**	**720,112**	**26.5**	**67.5**	**48.6**	**60.7**	**33.3**	**24.0**

[1] The fossil fuel comparator is 94 g CO_2eq/MJ fuel according to Directive (EU) 2015/652. [158]

The right half of Table 15 shows the resulting greenhouse gas emission savings when taking into account ILUC factors. The resulting emission savings are 24.0 Mtonne CO_{2eq}, a 50% decrease from the 48.6 Mtonne CO_{2eq} without ILUC factors. This decrease is mostly driven by the relatively high ILUC factors for most common biodiesel feedstocks, such as rapeseed, oil palm fruit and soybean (all 55 gCO_{2eq}/MJ).[159] The ILUC factors used in to come to the values in the table above are the mean values as presented in the ILUC Directive. When taking into account the ranges in ILUC emissions as presented in the same ILUC Directive, the resulting greenhouse gas emission savings related to the consumption of biofuels are ranging between 18.8 Mt CO2eq to 33.8 Mt CO2eq, with the 24.0 Mt CO2eq as the 'mean' value.

Biodiesel is particularly susceptible to ILUC factors because of the adjusted emissions savings of its feedstocks. 70% of biodiesel consumed in the EU comes from three feedstocks with a high ILUC factor: rapeseed, oil palm fruit and soybean, with respective shares of 32%, 23% and 15%. The ILUC factors for each of these are so high that the use of biodiesel made from these feedstocks could even be more emissions-intensive than the fossil fuel comparator benchmark (94 gCO_{2eq}/MJ), in effect creating "negative" savings. This happens when using the high range of the ILUC emissions (rather than the mean) or when using the 'default' emissions savings as indicated in the RED (instead of the actual reported emissions savings related to biofuels consumed).

5.3.1 ILUC science update

The concept of ILUC was brought into biofuel discussions over a decade ago, and since then new research has continuously been added to the growing body of knowledge on this topic. This section provides an overview of notable ILUC research literature that has been published since 2018. These studies are formative for developing new tools to measure ILUC impacts, performing updated regional ILUC assessments, and showcasing the potential impacts of different ILUC policies if implemented. They serve as a basis for discussion on the ILUC topic for policymakers, academics, and other stakeholders in the biofuel community.

Calculating the ILUC impact is a challenging exercise and methodologies are constantly evolving with new research, policy, and literature. ILUC impacts are typically calculated using large and complex models such as GLOBIOM[160] and GTAP-BIO[161] and ILUC outcomes are dictated by input data and methodological choices in these models. As ILUC criteria are being increasingly integrated into policy quantitatively, it is important that methodologies are continuously critically assessed, refined, and improved. A recent example of ILUC in policy is the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). In June 2019, the International Civil Aviation Organization (ICAO)

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[157] The typical savings are an aggregate result from combining the estimated feedstock shares with typical greenhouse gas saving values reported in the Renewable Energy Directive.
[158] Similar to the REDII, the simple average of the fossil fuel comparators for diesel and petrol was used: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015L0652&from=IT

[159] Source: Directive (EU) 2015/1513.
[160] GLOBIOM is a partial-equilibrium model developed by International Institute for Applied Systems Analysis (IIASA) that analyses the competition for land use between agriculture, forestry, and bioenergy. It has been used for the EC to quantify the land area and GHG impacts of ILUC from biofuels consumed in the EU. https://ec.europa.eu/energy/sites/ener/files/documents/Final%20Report_GLOBIOM_publication.pdf
[161] Global Trade Analysis Project (GTAP) is a computable general equilibrium model that evaluates costs of abatement and to assess the spill-over effects of greenhouse gases (GHG) abatement policies via international trade and sectoral interaction. The GTAP-BIO is an extension of this model to analyse biofuels and global land use. https://www.gtap.agecon.purdue.edu/models/energy/default.asp

released their methodology for calculating the default lifecycle emission values for CORSIA eligible fuels.

Indirect Land use Change (ILUC) can occur when land previously devoted to food or feed production is converted to produce biofuels, bioliquids and biomass fuels. In that case, food and feed demand still needs to be satisfied, which may lead to the extension of agricultural land into areas with high carbon stock such as forests, wetlands and peat land, causing additional greenhouse gas emissions. (Source: Commission delegated regulation (EU) 2019/807)

The methodology uses ILUC values from the GLOBIOM and GTAP-BIO models for various sustainable aviation fuel (SAF) pathways that differ by technology, region, and feedstock. Where the models have a discrepancy of greater than 10% of baseline GHG intensity for fossil kerosene, the lower value plus an adjustment factor of 4.45 gCO_2e/MJ is taken.[162] Cerulogy criticizes this methodological choice for calculating ILUC and argues that it introduces optimism bias, and more importantly is not analytically justified.[163] Malins, Plevin and Edwards looked at the recent adjustments to the GTAP-BIO model and its effects on lowering ILUC values. This study argues that the new adjustments to the model systematically underestimate ILUC emissions because the role of productivity increases has been increased as compared to land use changes in meeting feedstock demand.[164]

In contrast to large global models, other studies have focused on measuring ILUC impacts on a more localised and regional level, and new tools have also been developed to do so. Di Lucia et al. developed a causal-descriptive approach for project level assessment of ILUC called ILUC Project ASsessment Tool (ILUC PAST). The approach was tested with a case study in Sardinia on cellulosic ethanol production. The authors concluded that combining quantitative estimates of ILUC with the cause-and-effect dynamics from ILUC PAST are “sufficiently credible, salient and legitimate to support project level and local decision-making”. [165]

Elobeid, et al. showed that for regional assessments, there is a need to frequently evaluate and update land use change assessments as agricultural activities evolve in a region.[166] This paper first provided an overview of direct and indirect land use change, considerations of land use change for policy implementation, and used Brazil as evidence to illustrate factors relevant for the analysis of land use change. These factors included agricultural production trends, observed land use change based on land intensification (double cropping, increased yields), and extensification (land expansion) in response to price signals. The case study demonstrated that regional ILUC assessments need to be regularly updated as factors in Brazil including zoning restrictions, possibilities for double cropping, and stricter enforcement of policies can change over short periods.

Another area of recent ILUC research has focused on assessing the potential impacts of different policies on ILUC. The effects of these policies are then typically tested with a regional case study. Recent examples include:

- Brinkman, et al. performed a case study for Romania in which they calculated the rapeseed biodiesel potential and the GHG emissions of four measures to make surplus land available in 2020. The study found that low-ILUC-risk rapeseed biodiesel produced from surplus land has a

[162] CORSIA Eligible Fuels – Life Cycle Assessment Methodology, June 2019. https://www.icao.int/environmentalprotection/CORSIA/Documents/CORSIA%20Supporting%20Document_CORSIA%20Eligible%20Fuels_LCA%20Methodology.pdf
[163] Malins, Understanding the indirect land use change analysis for CORSIA (2019). https://www.transportenvironment.org/sites/te/files/publications/2019_12_Cerulogy_ILUC-in-CORSIA.pdf
[164] Malins, Chris, Richard Plevin, and Robert Edwards. "How robust are reductions in modeled estimates from GTAP-BIO of the indirect land use change induced by conventional biofuels?." Journal of Cleaner Production 258 (2020): 120716.
[165] Di Lucia, Lorenzo, et al. "Project level assessment of indirect land use changes arising from biofuel production." GCB Bioenergy 11.11 (2019): 1361-1375.
[166] Elobeid, Amani, et al. "Implications of biofuel production on direct and indirect land use change: Evidence from Brazil." Biofuels, Bioenergy and Food Security. Academic Press, 2019. 125-143.

potential of meeting 1-28% of the projected Romanian transport diesel consumption, mainly due to yield improvements in crop and livestock production[167].

- Van der Hilst, et al. spatiotemporally assessed the potential direct and indirect LUC dynamics from increased biofuel demand and the resulting GHG emissions, focusing on Brazil. They also analysed the potential effect of direct and indirect LUC mitigation measures such as increased agricultural productivity, shift to second-generation ethanol, and strict conservation policies. The study found that all LUC mitigation measures reduce the LUC-related GHG impact emissions from ethanol production, ranging from a 7-60% reduction.[168]

Other ILUC studies assess ILUC impacts by specific feedstock type as certain feedstocks have a larger concern for ILUC than others. Recent notable examples include:

- Strapasson, et al. assessed the land use changes from 1990 to the present for the major biodiesel crops, soybean, oil palm and oilseed rape in a study commissioned by the French vegetable oil and proteins sector. The study concluded that the emissions associated with ILUC for palm and soy are significant. For oilseed rape, there was no evidence found that this crop had high ILUC risk as the assessed countries showed net afforestation/reforestation in the past decade.[169]
- Dumortier, Elobeid and Carriguiry assessed the GHG emissions from LUC of corn ethanol in the US. Some have the concern that higher commodity prices from additional corn-based ethanol demand in the USA leads to LUC in the USA and globally, and subsequently increases overall GHG emissions. Others argue that this increased demand also leads to increased yields and can actually reduce LUC. This study concluded that a 15% increase in USA ethanol production results in a total expansion of global crop area by 1.2 million ha (0.25% compared to baseline). While some countries have a high yield gap and potential to increase yields with increasing commodity prices, others like the US, Brazil and EU countries are closer to the yield potential and less likely to have price-induced yield increase.[170]
- Pavlenko and Searle performed a review of 5 studies focused on the ILUC impact of energy crops. Although there was variance between studies which used different models with differing inputs (e.g. crop yields or share of land categories), nearly all the studies concluded that energy crop ILUC emissions are lower than those of food crops. However, energy cropping is still a nascent industry with limited empirical data, and improvements to modelling need to be made with more field data.[171]

While the relevance of ILUC has been established and there is evidence that ILUC can be avoided at a project basis, measuring of concrete ILUC factors remains complex despite new literature and research.

5.4 Local environmental impacts

Local environmental impacts related to biofuel production are addressed by Member States in their Progress Reports. Typical risks related to the most important crop country combinations are separately discussed at the end of this section.

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[167] Brinkman, Marnix LJ, et al. "Low-ILUC-risk rapeseed biodiesel: potential and indirect GHG emission effects in Eastern Romania." Biofuels (2018): 1-16.
[168] Van Der Hilst, Floor, et al. "Mapping land use changes resulting from biofuel production and the effect of mitigation measures." Gcb Bioenergy 10.11 (2018): 804-824.
[169] Strapasson, Alexandre, et al. "Land Use Change and the European Biofuels Policy: The expansion of oilseed feedstocks on lands with high carbon stocks." OCL 26 (2019): 39.
[170] Dumortier, Jerome, Amani Elobeid, and Miguel Carriquiry. "Assessing the possibility of price-induced yield improvements to reduce land-use change emissions from ethanol." Biofuels, Bioenergy and Food Security. Academic Press, 2019. 193-207.
[171] Pavlenko and Searle (2018). The International Council on Clean Transportataion. A Comparison of Induced Landuse Change Emissions Estimates from Energy Crops. https://theicct.org/sites/default/files/publications/ILUC-energy-crops_ICCT-White-Paper_06022018_vF1.pdf

5.4.1 Member States Progress Reports[172]

Most Member States indicated that within their country there is only limited domestic feedstock production for biofuels compared to total agricultural activities, and therefore consider that biofuel production causes no significant environmental impacts. Several Member States indicate that all agricultural production is regulated with respect to environmental impacts and therefore impacts of biofuel crop production are expected to be the same as those of other crop production. Several Member States also report that biofuels consumed in their country use voluntary schemes or national systems to provide proof that they originate from sustainable production. Detailed information per Member State is provided in Table 16.

Table 16. Information provided in MS Progress Reports to question 9.[173] Source: MS Progress Reports

Member State	Information reported on environmental impacts related to biofuel/bioliquid production
Austria	Evidence of source materials for biofuels produced sustainably in Austria is provided by means of a voluntary scheme or Agrarmarkt Austria's national sustainability system (AACS). Certification systems that demonstrate the sustainability of biofuels are listed in the elNa register. In the case of biodiesel, the voluntary system ISCC EU is used most (54%). For bioethanol, ISCC DE and ISCC EU have a combined market share of 64%. Austria developed a biofuels database and web-based platform to monitor trade flows and sustainability information of biofuels counted towards the national targets.
Belgium	The Belgium Progress Report only states that 'There are no known negative impacts on biodiversity, water and soil quality specifically due to the cultivation of biofuels.' No other information is provided.
Bulgaria	Bulgaria indicates that regional inspectorates for the environment and water prepare regional annual reports on the state of the environment and that for the reporting period, do not contain any information about ascertained harmful impacts or new circumstances relating to impact on biodiversity as a result of the production of biofuels for transport and other liquid fuels from biomass.
Croatia	The Croatian Progress Report reports no environmental impacts, as no agricultural land in Croatia is used for growing energy crops. Since 2015 there has been no biofuel production in Croatia.
Cyprus	Cyprus states that in 2017 and 2018 there was no significant domestic production and therefore that there are no impacts on biodiversity, water resources, water quality and soil quality in Cyprus.
Czechia	The Czech Progress Report indicates that all agricultural production within the Czech Republic is controlled within the framework of Good Agricultural and Environmental Conditions (GAEC). For this reason, they state that no impact is expected during the cultivation period. Also, it is mentioned that environmental impacts related to agriculture are routinely monitored and have not changed considerably over the past years. In the Progress Report extensive details are provided on the evidence to be provided for compliance with sustainability criteria by all actors in the supply chain.
Denmark	Denmark only states that domestic production has been so limited that, in the opinion of the Danish Energy Agency, there has not been significant impact related to biofuel/bioliquid production.
Estonia	The Estonian Progress Report only states that 'no biofuels are produced in Estonia, and as a result there are no impacts.' It also states that 'other agricultural activities are not known to have become more environment-intensive than usual.'
Finland	Finland indicates that biofuel production in Finland is based on material from domestic and imported waste and residues. They further state that monitoring is carried out within the framework of the national sustainability scheme. Finally, they mention that the production of biofuels cannot be assessed to have had an impact on any of these factors in Finland.
France	The French Progress Report only states that 'the impact of biofuel production on these natural resources has not been assessed in the last two years.'
Germany	The German Progress Report indicates that it is difficult to link impacts of biofuel production to the overall agricultural system. It also indicates that more intensive utilisation of agricultural land in Germany essentially increases risks to biodiversity, water resources, water and soil quality and the state of terrestrial ecosystems. The report mentions that several risks are linked to the more intensive use of agricultural land (e.g. nitrogen leakage to water, bird loss). The report specifically mentions the importance of leaving rapeseed straw on the field for humus balance, stating that the use of rapeseed straw for biofuels presents a significant risk to the humus balance of the soil.
Greece	Greece indicates that no specific study has been performed on this topic so far. The final statement in the report is that no significant impact is expected due to the small-scale energy crops cultivated in the country and the appropriate legislation issued and applied.
Hungary	Hungary provides details on land use for different crops in the country and conclude that the production of raw materials in Hungary for the implementation of the Renewable Energy Directive had no effect on biodiversity, water resources, water quality or soil quality.
Ireland	Ireland indicates that all feedstock for domestic biofuel production was waste products or residues from meat processing, which do not have an impact on food or feed or on soil and the ecosystem.

[172] Available at https://ec.europa.eu/energy/en/topics/renewable-energy/progress-reports
[173] Question 9: 'please provide information on the estimated impacts of biofuels and bioliquids on biodiversity, water resources, water quality and soil quality within your country in the preceding two years'.

Member State	Information reported on environmental impacts related to biofuel/bioliquid production
	They indicate that there were no detectable impacts on biodiversity, water resources, water quality, and soil quality. In an annex they provide information on the voluntary schemes used to demonstrate compliance.
Italy	The Italian Progress Report states that land use for energy crop production is limited, and therefore that its impact on biodiversity, water resources and soil quality - is negligible. They finally state that the growing focus on the sustainability of bioliquids and biofuels has entailed a constant commitment to guarantee an ecological balance and protect biodiversity.
Latvia	The Latvian Progress Report indicates that no studies were conducted to assess these impacts. They provide some more details on the type of crops used for biofuel production and the recent fluctuations in amounts of biofuels produced and land used for crop production. No other information is provided.
Lithuania	Lithuania states that the Lithuanian Ministry of the Environment did not provide any information on the estimated impacts of the production of biofuels and bioliquids on biodiversity, water resources, water quality and soil quality.
Luxembourg	Luxembourg indicates that compared to the last two progress report there is no change to information on the expected impacts. No other information is provided.
Malta	Malta indicates that local biofuel production derived mainly from waste cooking oil waste streams. Thus, there was minimal, if any, negative impact on biodiversity, water resources, water quality and soil quality. The sole local manufacturer of biofuels had to abide to Integrated Pollution Prevention and Control regulations. This local production was considered to have a positive impact on the environment as it reused its waste. The local production ceased its operations in December of 2017, and as of currently, all biofuels contributing to the RES share are being imported.
Netherlands	The Dutch report states that hardly any raw materials for biofuels are grown in the Netherlands. In addition, practically no new agricultural land has been brought into use. For this reason, the impact on biodiversity, water resources, water quality and soil quality as a result of growing crops for the production of biofuels is immaterial in the Netherlands.
Poland	The Polish Progress Report indicates that the environmental impacts have been analysed and addresses the possible environmental impacts related to biomass cultivation, biofuel production and biofuel use. The report states that the analysis showed that the cultivation of crops intended for biofuel production does not have a greater impact on soil quality and water resources than the cultivation of the same crops for food purposes. The report further indicates that the production of biofuel components in Poland does not adversely affect the environment as it mentions that this is based on “high security and environmental standards”. Finally, regarding the use of biofuels, the report indicates that biofuel use reduces the emission of pollutants into the environment, except for nitrogen oxides, whose share in exhaust gases increases.
Portugal	Portugal states that given the low levels of endogenous agricultural material used in the production of biofuels, it does not appear that at national level, there is any impact on biodiversity, water resources or soil quality.
Romania	The Romanian Progress Report provides a detailed description of how the sustainability criteria were implemented within Romania. It does not provide any additional information on actual environmental impacts related to biofuel consumption.
Slovakia	Slovakia indicates that farmers/suppliers of biomass have to be able to provide a declaration stating that the requirement for good agricultural and environmental condition has been met. The report adds that at the moment, there is no relevant data on the adverse impact of producing biofuels on biodiversity, water resources, water quality or soil quality. The report assumes that these impacts are negligible, since the area of crops cultivated for biofuels in 2010 to 2018 in Slovakia did not increase significantly compared to the previous period.
Slovenia	The Slovenian Progress Report only provides the statement that there was no domestic production of biofuels in Slovenia.
Spain	Spain states that environmental impacts are negligible due to the limited use of domestic feedstocks for biofuel production. The report indicates that no specific reporting on these types of impacts is done by economic operators. No additional information is provided.
Sweden	The Swedish Progress Report indicates that at an aggregated level there is no reason to believe that the cultivation of raw materials for biofuels is leading to the use of land of high natural value. Also, the report indicates that impacts on water are not relevant for the Swedish case, since cereals and other crops that are used to produce biofuels are not irrigated, not even in years when there is a drought. Regarding soil and water quality, the report states that since no new agricultural land is deemed to have been given over to the current production of crops for biofuels, it is assumed that these crops do not contribute to any direct changes in stored carbon in the soil that need to be taken into account in this context. However, as is the case for food production, the production of biofuels results in emissions of acidifying and eutrophying substances, which in turn affect land and water quality.
UK	The UK Progress Report indicates that the Joint Nature Conservation Committee has published a report on the potential impacts related to biofuel production in 2013. The report also states that a recent update was published on broader biodiversity indicators. No conclusions of these reports are summarized in the Progress Report.

5.4.2 Analysis of local environmental risks in a selection of countries of production

The risks of local environmental impacts have been assessed for the main crop/country combinations that are representative of biofuel consumption in the EU in 2018. For each of the impact categories (soil, water, air and biodiversity), an assessment was done of typical environmental risks associated with the feedstock in a specific country. The analysis shows that the geographical contexts covered in this report are quite heterogeneous and agricultural supply chains tend to be characterised by a high degree of site-specificity. This means that it is not always possible to say with certainty whether identified risks are present in the specific supply chains delivering feedstock to EU biofuels.

The implementation of the EU biofuel sustainability criteria minimizes environmental impacts associated to agricultural feedstock for biofuel production. Voluntary schemes help to ensure that biofuels comply with the EU sustainability criteria, checking that; production of biofuel feedstock does not take place on land with high biodiversity, land with a high amount of carbon has not been converted for biofuel feedstock production, and the production of biofuels leads to sufficient greenhouse gas emissions savings. Several voluntary schemes also consider additional sustainability aspects such as soil, water, air protection and social criteria. However, this does not completely avoid impacts, and a continued effort is needed to decrease impact and increase insights in the size of these impacts.

Agricultural intensification and growing demand for food and fuels pose great pressures on the environment. The analysis shows that for all crop-country combinations, serious impacts on water, soil and air have to be taken into account. These environmental impacts are often closely interconnected, therefore one pressure can have a cascading effect on the whole agro-ecosystem. Ecosystem functioning and biodiversity is of great importance for agriculture. For example, processes such as of pollination by insects, biological pest control, maintenance of soil quality by soil organisms, and nutrient cycling by microorganisms can play a significant role in achieving good yields. It is expected that agriculture will face more challenges in the future due to a changing climate, increasing levels of water scarcity and limited availability of arable land.

All these aspects and challenges differ per feedstocks and regions of origin as shown inTable 17. A detailed exploration of potential local environmental risks can be found in Appendix C.

Table 17. Relevant environmental risks and impacts per crop-country combination

	EU *Rapeseed, wheat, maize, sugar beet*	Indonesia & Malaysia *Palm oil*	Argentina *Soy*
Water	• Eutrophication of water bodies through run-off and leaching of nitrogen-based fertilisers • Water abstraction leading to water scarcity	• Leaching of nutrients and organic matter through soil erosion and sedimentation • Water pollution through discarded wastewater from palm oil mills (palm oil mill effluent)	• Eutrophication of water bodies through run-off and leaching of nitrogen-based fertilisers (especially glyphosate) • Unsustainable water use and contamination straining the Guarani Aquifer
Soil	• Soil erosion through wind, water or harvest losses • Soil compaction as a result from heavy machinery use • Soil organic carbon loss through erosion, climate change and drainage of soils • Soil contamination through accumulation of pesticide residues	• High soil erosion rates leading to river constriction, increased flooding, threatened aquatic habitats, leaching of nutrients and organic matter and silt deposits in rivers and ports • Soil compaction due to heavy machinery use related to increased size of plantations	• Soil erosion and deterioration through soybean cultivation on fragile soils • Soil contamination through increased application of herbicides
Air	• Air pollution through spreading of fertilisers and pesticides	• Air pollution through haze related to burning as land preparation, agrochemical application and processing emissions	• Air pollution through burning of crop residues and other waste
Biodiversity	• Eutrophication of aquatic and terrestrial ecosystems leading to decrease in biodiversity and invasion of species • Decline in soil organisms through decreased soil quality	• Habitat and biodiversity loss through indirect displacement effects • Decreasing soil biodiversity due to extensive use of herbicides	• Habitat and biodiversity loss through indirect displacement effects • Loss of local biodiversity through intensification of farming

5.5 Relevant international conventions

The Renewable Energy Directive requires insight into whether countries that supply a significant source of raw material for biofuels consumed within the Community, have ratified and implemented each of the following Conventions of the International Labour Organization, and international conventions related to biodiversity:

- Forced Labour Convention 1930 (ILO 29).
- Freedom of Association and Protection of the Right to Organize (ILO 87).
- Application of the Principles of the Right to Organize and to Bargain Collectively (ILO 98).
- Equal Remuneration of Men and Women Workers for Work of Equal Value (ILO 100).
- Abolition of Forced Labour (ILO 105).
- Discrimination in Respect of Employment and Occupation (ILO 111).
- Minimum Age for Admission to Employment (ILO 138).
- The Prohibition and Immediate Action for the Elimination of the Worst Forms of Child Labour (ILO 182).
- Cartagena Protocol on Biosafety to the Convention on Biological Diversity (CPB).
- Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

In the following tables and paragraphs, we provide insights in the status of ratification of the different conventions and the comments ILO provided to the country on enforcement of the ratified conventions.

Table 18. Ratification of international conventions as appear in the Renewable Energy Directive 2010 (changes from 2008 cited below) in main countries providing EU biofuels[1) 2)]

	ILO 29	ILO 87	ILO 98	ILO 100	ILO 105	ILO 111	ILO 138	ILO 182	CPB 2)	CITES 3)
Argentina	√	√	√	√	√	√	√	√	-[174]	R
Indonesia	√	√	√	√	√	√	√	√	R	ACS
Malaysia	√		√	√			√	√	R	ACS
Ukraine	√	√	√	√	√	√	√	√	ACS	ACS
USA					√			√	-	R
EU 28	√	√	√	√	√	√	√	√	See Table 19	

1) Sources: ILO web site http://www.ilo.org/dyn/normlex/en/f?p=1000:11400:3969178755425480::NO:::, CPB website : http://bch.cbd.int/protocol/parties/ and CITES website: http://www.cites.org/eng/disc/parties/alphabet.php
2) Abbreviations stand for the various administrative options: R= Ratified, A= Accepted, ACS = Accession, AP= Approval, S = Succession, C=Continuation. √ stands for ratified.
3) Cartagena Protocol on Biosafety.
4) Convention on International Trade in Endangered Species of Wild Fauna and Flora.

Table 19. Ratification of biodiversity conventions as mentioned in the Renewable Energy Directive for EU28[1) 2)]

Country	CPB	CITES	Country	CPB	CITES
Austria	R	ACS	Latvia	ACS	ACS
Belgium	R	R	Lithuania	R	ACS
Bulgaria	R	ACS	Luxembourg	R	R
Croatia	R	ACS	Hungary	R	ACS
Cyprus	ACS	R	Malta	ACS	ACS
Czech Republic	R	S	Netherlands	A	R
Denmark	R	R	Poland	R	R
Estonia	R	ACS	Portugal	A	R
Finland	R	ACS	Romania	R	ACS
France	AP	AP	Slovakia	R	S
Germany	R	R	Slovenia	R	ACS
Greece	R	ACS	Spain	R	ACS
Ireland	R	R	Sweden	R	R
Italy	R	R	UK	R	R

1) Sources: CPB website: http://bch.cbd.int/protocol/parties/ and CITES website: http://www.cites.org/eng/disc/parties/alphabet.php
2) Abbreviations stand for the various administrative options: R= Ratified, A= Accepted, ACS = Accession, AP= Approval, S = Succession, C=Continuation.

Table 18 shows that ILO conventions have been ratified in several of the countries important for providing the EU biofuels feedstock. Only the USA has not ratified most of the ILO conventions. Also, Malaysia has not ratified some of them. Compared to previous assessment in 2018, the progress in these countries is limited and not resulting in any changes in ratifications. An overall argument given by the USA is that they have difficulty of imposing legislation through their federal structure and can therefore not ratify or implement many of the ILO conventions.

The ratification of ILO conventions alone says little regarding their enforcement. The ILO committee monitors the ratification of the conventions and also their integration into existing or future legislation. The committee provides countries with comments, feedback and questions regarding elements they do not fully see as enforced or implemented in national legislation or programmes.

Several European countries received comments, mostly on ILO 29 (forced labour especially related to migrant workers) ILO 87 (issues with trade unions) and ILO 98 (collective bargaining/agreements), ILO 100 (equal remuneration) and ILO 111 (discrimination). Only Finland, Italy, Latvia, Lithuania,

[174] Argentina has signed the protocol on 24th of May 2000, but has not ratified or implemented the protocol.

Luxembourg, the Netherlands and Sweden did not receive any comments on the selection of ILO conventions under review here.

For the countries outside the EU, no comments were provided for Indonesia and Ukraine by the ILO committee on any of the conventions named in Table 18. For Argentina comments were provided on ILO 87 (issues with trade unions and right to strikes) and ILO 98 (potential restrictions on collective bargaining). For Malaysia comments were provided on ILO 100 (equal remuneration). For the USA comments are provided on ILO 182 (protection of child agricultural workers from hazardous work).

For some countries, international NGOs claim practices like forced labour or child labour are taking place on agricultural plantations which is not signalled by ILO. The ILAB (Bureau of International Labour Affairs) published a report (published 2018[175]) of goods where child or forced labour sometimes occurs in their production. Examples on that list are Indonesian oil palm (child labour) and Malaysian oil palm (child labour and forced labour). In the frame of the current study it is impossible to verify whether this is correct or has taken place at the plantations producing feedstock for biofuels supply chains.

Due to the relatively slow ratification of ILO conventions, few changes in the past period (2014-2020) and recurring concerns raised about the enforcement, ILO conventions have only limited power in safeguarding the sustainability of biofuels. We have not assessed in detail whether conventions are implemented in the national legislative and regulatory frameworks.

Table 18 shows that countries outside the EU have mostly ratified or are in the process of ratifying CITES. However, the Cartagena Protocol on Biosafety (CPB) is less commonly ratified. Argentina and the USA have neither ratified nor accepted the convention. Table 19 shows that all Member States have accepted or ratified the CPB and CITES conventions.

[175] https://www.dol.gov/sites/dolgov/files/ILAB/ListofGoods.pdf

6. Economic, and social impacts related to biomass

The Renewable Energy Directive requires the Commission to report on a range of socio-economic impacts in the Community and in third countries related to an increased demand for biofuels. This includes the availability of foodstuffs at affordable prices, in particular for people living in developing countries, and wider development issues.

In this chapter we analyse several economic and social impacts related to biofuels consumption in the EU. Firstly, we analyse possible impacts on food prices and food affordability; secondly, we analyse impacts on labour and employment and finally we discuss impacts on other sectors that use the same biomass feedstocks. The Commission is also required to report on ratification and implementation of Conventions of the International Labour Organisation. These were addressed in Section 5.5, together with conventions on biodiversity.

In terms of the influence of biofuels on food prices, studies have historically shown that increased demand in biofuels in the EU did not directly cause the food price spikes observed in 2008. Recent studies have confirmed this conclusion and find that biofuels are not a main leading source of increased food prices, rather they are linked more so to energy prices. Regardless, this is a topic that should be continued to be researched and monitored, especially in developing countries.

In regard to employment, it is estimated that the biofuel industry in Europe employed 248,200 in 2018. Most of the employment is observed in Romania, Poland, and France. Although some employment is temporary construction jobs for biofuel production facilities, roughly a third are permanent biofuel facility or agricultural jobs.

A wide range of different biomass feedstocks can be used for biofuel and bioenergy production (e.g. in the heat and power sector). Several of these feedstocks are also used in other sectors for material, animal feed or other applications. Increased use of biomass for energy applications can potentially lead to negative impacts for these other sectors that also use biomass. At the moment, this is not likely, as for many feedstocks there is surplus biomass available which can be used for bioenergy. However, just like food prices, this is a topic which should continue to be monitored to avoid unsustainable practices. Biorefineries could be a potential solution to using biomass more efficiently and reduce competition with other sectors.

6.1 Food prices and affordability

As most biofuels are produced from food crops, stakeholders are concerned that biofuels compete with food production and that this competition drives up food prices and price volatility and causes hunger.

To understand the true impact, the following elements are most relevant:

- Factors influencing international/global food prices, and of other related commodities
- Interaction between global and local food/agricultural markets
- Local food affordability, and food prices

6.1.1 Global food prices

Concerns about the impact of biofuels on food security follow from the argument that an increasing application of basic agricultural commodities for biofuels production leads to crop shortages and increasing food commodity prices.

Figure 28 shows a composite food price index and annual biofuels production volumes. The price surge up to the July 2008 climax coincides with increasing growth in global biofuels production. Over the next half year however, biofuel production continues to increase while crop prices drop. This counters the idea that increased biofuel production leads to crop shortages, which eventually lead to increasing food commodity prices. The graph also shows that biofuel production is fairly stable from 2010-2011, while another price spike in crop prices occurs in 2011. In the past few years, biofuel production has continued to increase while crop prices have been stable or are even slightly declining. This suggests that there is no direct, or even indirect, correlation between crop prices and increasing biofuel production over the assessed period.

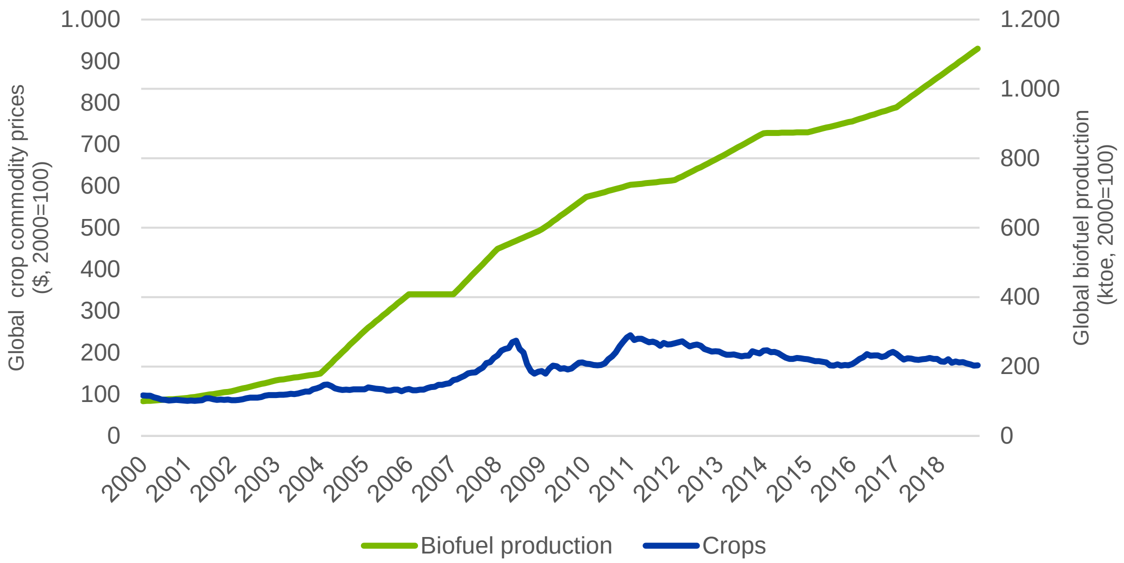

Figure 28. Global crop commodity prices and the aggregated price of all commodities,[176] versus global biofuels production volume,[177] both normalised

Ecofys 2013 reviewed several studies and found that biofuels did not cause the price spikes, but that their impact is likely more nuanced.[178,] A strong demand for crop-based biofuels could have an impact on the price of feedstock but this leads only to small variations on global agricultural commodity prices (which cover much larger volumes of crops), and thus a direct strong impact cannot be observed. Recent research has updated and confirmed this conclusion and also finds that price series data show that biofuels are not a main leading source of increased food prices (and consequently food shortages). [179] Food prices are more so linked to energy prices, as an increase in energy prices subsequently increases the production and transportation costs of food production. Despite a weak linkage between food prices and biofuel production, some criticise biofuel mandates as they create an inelastic demand and do not have the flexibility to respond to food price volatility. [180]

For the future, Thomson and Meyer, 2013 expect the strongest biofuel consumption growth in developing countries and even argue that second generation biofuels can help food security.[181] The impacts depend on whether the feedstock competes with traditional crops or is a co-product; biofuel from crop residues such as corn stover and wheat straw can lead to more efficient land use (higher biofuel yield per hectare), potentially reducing food and feed prices.

The discussion of biofuel production and food price volatility is a complex one as economies are shaped by a diverse and interconnected range of forces. The majority of current research argues that

[176] World Bank, 2013, World DataBank - Global Economic Monitor (GEM) Commodities, accessed June 2020. The food price index is derived by averaging all food/crop commodities in the World Bank monitor on commodity prices.
[177]Statista, Global biofuel production from 2000 to 2018.
[178] For an overview and discussion of studies, see [Ecofys 2013, Biofuels and food security].
[179] Filip, Ondrej, et al. "Food versus fuel: An updated and expanded evidence." Energy Economics 82 (2019): 152-166.
[180] Tadasse, Getaw, et al. "Drivers and triggers of international food price spikes and volatility." Food price volatility and its implications for food security and policy. Springer, Cham, 2016. 59-82.
[181] Thomson and Meyer, 2013, Second generation biofuels and food crops: Co-products or competitors?, Global Food Security 2(2):89-96]., Also see extensive work by FAO on their Bioenergy and Food Security (BEFS) approach.

increasing biofuel production does not have a negative effect on food security or food prices, however this is a topic that should be continued to be researched and monitored.

6.1.2 Food prices in Member State Progress Reports

In the Member States Progress Reports[182] any changes in commodity prices associated with increased use of biomass within their Member State have to be reported. In the recent Progress Reports, most Member States report that they do not see a relation between commodity prices and biofuel production, or that they did not see any fluctuations in their domestic food prices related to biofuel production. Several Member States (e.g. Austria, Lithuania, Spain, Poland, Sweden) point to yield, availability of biomass or international commodity prices as reasons for fluctuations in food prices. Other Member States (Bulgaria, France, Hungary, Italy, Slovenia, Latvia, Greece, Sweden, Slovakia and the UK) provide overviews of prices for crops or woody biomass products, of which most give no analysis/conclusions or indicate that no link can be made based on the presented data. Luxembourg indicates that no robust data on raw material prices is available because most of the plants dedicated for energy purposes are internally used in the biogas plant attached to the farm. So, no real market exists.

Germany presented an extensive analysis of a range of different biomass feedstock types (e.g. wood chips, logs, vegetable oils, biogas substrates). For most woody biomass, prices increased until 2014/2015 and decreased until 2016. Since 2016 most prices increased, e.g. for wood pellets and briquettes by 7-10%. This development partly reflects the development in heating oil prices that strongly influence the price of wood pellets.

For vegetable oils, Germany indicates that their prices are largely determined by the world market. In the reporting period, prices for palm oil and soy oil decreased due to a high supply of palm oil from Malaysia and Indonesia and a low demand as a result of the trading dispute between the USA and China. Nevertheless, the prices of rapeseed increased in the second half of 2018 as the drought in Europe and Australia led to low harvests. Prices of biogas substrates are less dependent on the world market and vary strongly, even between regions. Still, a positive trend in the prices of biogas substrates could be observed in 2018 because of the drought.

6.2 Labor and (local) employment

The biofuel industry plays an important role in employment in the EU as it creates many jobs along the supply chain, from feedstock cultivation to biofuel production facilities. IRENA estimates that globally, liquid biofuels employed 2 million in 2018, with the majority of jobs in planting and harvesting biomass feedstocks. Fuel processing facilities comprise a smaller share of employment, but tend to require more technical expertise, are higher paid, and create higher value in the supply chain. Brazil represents the largest share of the workforce, with 832,00 jobs in biofuel related industry and the USA the second largest with 311,000 jobs.[183]

For the EU, it is estimated that the biofuel industry employed 248,200 in 2018, making biofuels the third largest renewable energy job creator after wind energy and solid biomass (314,000 and 387,000). Based on modelling of the biofuel industry, including agricultural activities, the countries with the greatest employment are Romania (40,000 jobs) and Poland (41,200 jobs) due to their large agricultural land area. France is the third largest (29,100 jobs) as it has both biofuel production facilities and feedstock production. As biofuel mandates increase in MS and overall demand

[182] Available at https://ec.europa.eu/energy/en/topics/renewable-energy/progress-reports
[183] IRENA, Renewable Energy and Jobs Annual Review 2019.

increases, this is expected to stabilise the important socioeconomic role of the biofuel industry in total employment in the EU.[184]

One study estimated the potential jobs created if each Member State were to use the sustainable available waste feedstocks for advanced biofuel production.[185] The countries with the highest job creation were France (38,000-78,000 jobs), Germany (32,000-70,000 jobs), and Romania (10,000-18,000 jobs) as these are the countries with the greatest waste feedstock availability. While 70% of these are temporary construction jobs, 30% are permanent biofuel facility or agricultural jobs.

Although there is a range in job quality (e.g. pay, permanency) and variance in number of biofuel jobs among MS, it is apparent that the biofuel industry can play a positive role for employment in the EU.

6.3 Impact on other biomass using sectors

A wide range of different biomass feedstocks can be used for biofuel and bioenergy production (e.g. in the heat and power sector). Several of these feedstocks are also used in other sectors for material, animal feed or other applications. Increased use of biomass for energy applications can potentially lead to negative impacts for these other sectors that also use biomass.

Table 20 provides an overview of biomass feedstock types and their current uses in non-bioenergy sectors. Several of these feedstock types are included in Annex IX Part A of the ILUC Directive, like biomass residues from forestry and straw, while UCO and animal fats (Category 1 and 2) are included in Part B of Annex IX.

Table 20. Biomass feedstock types and their possible uses

Type of feedstock	Raw material	Existing use					
Woody residues[186]		Left in forest	Pulp, paper & panel board production	Mulch	Animal bedding	Landscaping, playground surfacing	Wood pellet or briquette production
	Bark	X		X		X	
	Branches (incl. tops)	X	X	X	X	X	X
	Leaves (and needles)	X					
	Sawdust from forestry operations	X			X		
	Sawdust & cutter shavings from sawmills		X				X
Straw		Incorporation in soil	Animal bedding & feed	Mushroom & strawberry production	Frost protection & thatching	Building materials	Paper & Pulp
	Any straw	X					
	Cereal straw		X	X	X	X	X

[184] EurObserv'er, The State of Renewable Energies in Europe, 2019. https://www.eurobserv-er.org/category/all-annual-overview-barometers/

[185] S.Y. Searle, C.J. Malins, Waste and residue availability for advanced biofuel production in EU Member States, Biomass and Bioenergy (2016), http://dx.doi.org/10.1016/j.biombioe.2016.01.008

[186] Including forestry residues from managed forests, arboricultural residues, woody farm residues, sawmill residues.

Type of feedstock	Raw material	Existing use		
Used cooking oil[187]		Animal feed (restricted in the EU & some 3rd countries)	Oleochemicals (detergents, soap, cosmetics, etc.)	
	UCO	X	X	
Animal fats (tallow)		Process fuel in the rendering facility for process heat and power	Oleochemicals (detergents, soap, cosmetics etc.)	Pet food and animal feed
	Category 1 animal fats	X		
	Category 3 animal fats		X	X
Crude tall oil		Distilled into a variety of products (e.g. glues, primers)	Process fuel in the pulp mill lime kiln	Used as petroleum extraction drilling fluid or in phosphate mining
	Crude tall oil	X	X	X
Fatty acids		Animal feed	Oleochemical products (detergents, soap, cosmetics etc.)	Recycled paper de-inking
	All fatty acids		X	X
	High quality fatty acids	X		
Cobs cleaned of kernels of corn		Activated carbon	Livestock bedding & animal feed	Industrial source of furfural
	Corn cobs	X	X	X

For **forestry biomass,** the level of competition varies by type of raw material, cultivation and extraction method, and sector. The forestry sector is a relatively complex economic sector, with various residue streams and recovered products that need to be considered in the balance. As displayed in Figure 29 which shows the woody biomass balance in the EU in 2015, woody biomass has demand from the construction, paper and paperboard, and bioenergy industries. Construction wood mainly relies on large diameter logs, meaning the sawn wood/sawmill subsector, and nearly half of this ends up as a residue going to the pulp or panel industry. Therefore, wood-based construction is an important driver for raw material availability for pulp and paper and for emerging industries, as sawmilling generates raw materials for these industries (wood chips, bark, sawdust, etc). For bioenergy, just under half of the woody biomass is by products from the pulp, sawmill, and panel industries, with the remainder from roundwood. This shows that there is potential competition for roundwood used for bioenergy and these other industries, but that bioenergy also works with them synergistically as it also relies on these industries' by-products.

Several studies have explored the growth and availability of wood from EU forests which allow us to further examine the competition between industries and potential for bioenergy. One potential woody biomass stream is forestry residues; a significant portion of these forestry residues (>90%) are currently left in forests and could (if harvested/extracted to a sustainable limit) be used for bioenergy purposes without competition. A sustainable limit refers to the fact that some residues need to be left in the forest to retain soil quality and forest productivity.[188] Searle and Malins estimate the availability of forestry residues at nearly 68 million tonnes (dry basis). While 46 million tonnes should be kept on soil to retain quality, 12.3 million tonnes are still available for heat and power and a remaining 9.2 million tonnes for biofuel production.[189] If these resources were mobilised, this could potentially reduce competition between bioenergy and other sectors. European Forestry Institute (EFI) recently estimated that 44 Tg (44 million tonnes) a year of logging residues (branches and harvesting losses)

[187] Note that in some Asian countries UCO has historically been re-used as cooking oil (termed 'Gutter oil') by simple cleaning and mixing with virgin cooking oil. This practice is, however, illegal in some countries (notably in China) and therefore not included in the table.
[188] JRC, Biomass production, supply, uses and flows in the European Union, (2018).
[189] S.Y. Searle, C.J. Malins, Waste and residue availability for advanced biofuel production in EU Member States, Biomass and Bioenergy (2016), http://dx.doi.org/10.1016/j.biombioe.2016.01.008

are available in Europe, however a large part of this is already used to produce materials and energy.[190]

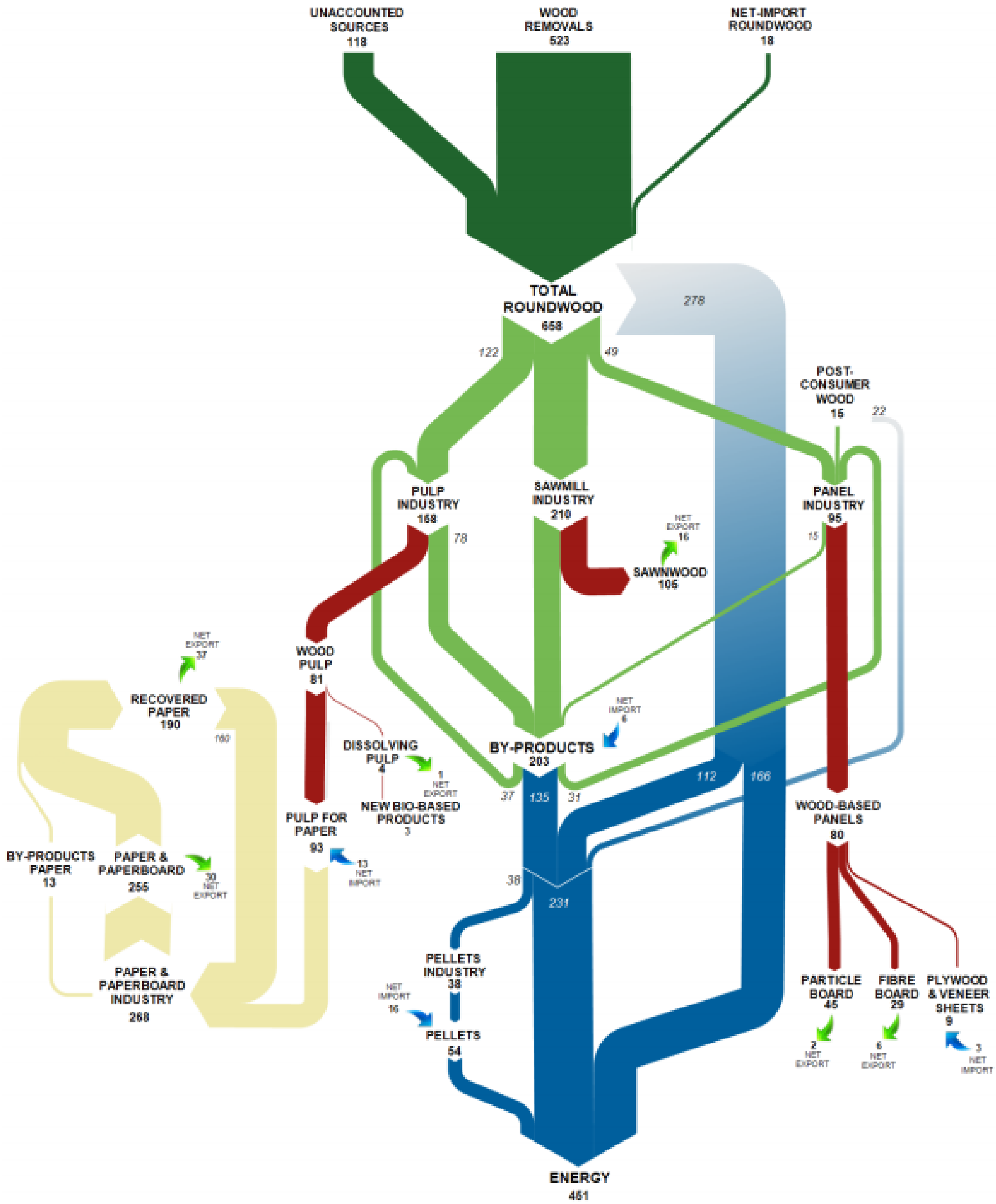

Figure 29. EU's woody biomass balance in 2015 (units in Mm^3)[191]

[190] Verkerk, P. J., Fitzgerald, J. B., Datta, P., Dees, M., Hengeveld, G. M., Lindner, M., & Zudin, S. (2019). Spatial distribution of the potential forest biomass availability in Europe. Forest Ecosystems, 6(1), 5.
[191] JRC (2019), 'Sankey diagrams of woody biomass flows in the EU-28', https://publications.jrc.ec.europa.eu/repository/bitstream/JRC115777/jrc_sankey_2019_online.pdf

A share of **straw** can be sustainably removed from the field for use as bioenergy feedstock. However, some straw should be left in the field to maintain soil quality and soil carbon. The sustainable removal rate depends on local conditions as well as the soil management practices applied (e.g. low or no till agriculture, use of cover crops and crop rotation).[192] Several Member States have a straw surplus (in particular France, Germany and Spain), that could sustainably be harvested and used for bioenergy production. According to Ecofys 2013,[193] an estimated total of 21.4 Mtonne of low ILUC cereal straw[194] was available in the EU (top 12 straw producing Member States) in 2013. Searle and Malins looked at a wider range of agricultural residues (including more crops, but also other residues). They estimated that of the available 316 million tonnes (dry basis), 196 million tonnes should not be removed to retain soil quality. There remain 9.8 million tonnes for heat, power, and biogas, 26.4 million tonnes for other uses, and 84.6 million tonnes for biofuel production. [195] A study by JRC estimated slightly higher amounts and concluded that all agricultural residues in the EU amount to 440 million tonnes. Of this, wheat residues represent 149 million tonnes and maize residues 80 million tonnes.[196]

An estimated 90% of the currently collected EU supply of **used cooking oil (UCO)** is used for biofuel or bioenergy production,[197] with the remainder used in the oleochemical industry.[198] Importantly, use of UCO as animal feed has been restricted in the EU since 2002 as a reaction to the BSE[199] crisis, and subsequent implementation of the Animal-By-Products Regulation EC 1774/2002. Only a few high-quality sources of vegetable oil UCO, such as from food manufacturing processes where the inputs are pure and uniform and the processes are well controlled, are permitted to be used for animal feed. Outside of the EU, biofuel production is the prevalent use for collected UCO, either directly within the country of collection, or for use in the EU. Use of UCO for animal feed is also restricted in some overseas markets, including in the USA as of 2017[200] and China. There is room for increased use without severe competition with other current uses as in many markets there is still significant potential to scale up the collection of UCO. Within Europe, the main potential exists in the collection of UCO from households (as discussed in section 2.3).

For **animal fats,[201]** nearly 80% of the EU supply of 2.1 Mtonne Category 3 animal fats was used in the oleochemical industry or as animal feed and only 0.43 Mtonne (~20%) was used for biodiesel production in 2018.[202] Competition will occur if increased volumes are diverted to biofuel or bioenergy production. Category 3 animal fats are not included in Annex IX part B (which only includes categories 1 and 2), and thus not counted double towards the target for RES-T. Around 80% of the available Category 1 and 2 animal fats (0.62 Mtonne) is already used for biodiesel production (0.51 Mtonne), with the remainder being used as a process fuel at the rendering facility. Competition with other uses is very limited. Category 1 material needs to be disposed of, either by incineration or as a fuel for combustion, whereas the use of Category 2 animals fats is restricted to specific technical industrial uses (around 1.5 ktonne).

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[192] REDIIBIO project, Technical Assistance to develop guidance for the implementation of the new bioenergy sustainability criteria set out in the revised Renewable Energy Directive
[193] Ecofys 2013, Low ILUC potential of wastes and residues for biofuels
[194] Based on wheat, barley, oat, rye and triticale. Rapeseed straw and sunflower straw are not typically collected in the EU. Additional potential could be realised from corn straw (commonly termed “corn stover”).
[195] S.Y. Searle, C.J. Malins, Waste and residue availability for advanced biofuel production in EU Member States, Biomass and Bioenergy (2016), http://dx.doi.org/10.1016/j.biombioe.2016.01.008
[196] JRC, Biomass production, supply, uses and flows in the European Union, (2018).
[197] Ecofys 2013, Low ILUC potential of wastes and residues for biofuels
[198] UCO is not a preferred feedstock for the oleochemical industry, which requires oils with a consistent carbon chain length and saturation.
[199] Bovine spongiform encephalopathy (BSE) is an animal disease also known as “mad cow” disease.
[200] International Magazine of Rendering, *US Market Report*, April 2019.
[201] The Animal By-product Regulation classifies materials into 3 categories according to their potential risk posed to human health. Category 1 material has the highest risk of spreading disease such as BSE and includes the bovine spinal cord, pet animals, zoo and circus animals, wild animals suspected of carrying a disease, and catering waste from international transport. Category 2 material is also high risk material, and includes fallen stock and digestive content. Category 2 is also the default status of any material that does not fall into Categories 1 or 3. Category 3 material is the lowest risk material. It represents parts of the animals that have been passed as fit for human consumption. However, it is generally not used for human food, either because it is made out of non-edible parts (e.g. hides, hair, feathers, bones) or for commercial reasons. When products of different categories are mixed, the entire mix is classified according to the lowest category in the mix.

[202] European Fat Processors and Renderers Association (EFPRA), June 2019, https://www.efpralabaule2019.com/docs/dobbelaere.pdf.

Crude tall oil (CTO) is only available in limited supply as a by-product of the Kraft chemical wood pulping process (total potential CTO supply is around 2.6 Mtonne). Current demand is around 1.75 Mtonne, of which an estimated 80% is distilled to derive a number of products[203]. This implies that there is a potential surplus of about 0.85 Mtonne of CTO that could be accessed (besides the 0.23 Mtonne currently used for biofuel production). Accessing this potential will require modifications at some plants to process (acidulate) crude sulphate soap to CTO, rather than to burn it directly as a process fuel at the pulp plant.[204]

For **fatty acids** there is considerable current use in oleochemical and animal feed sectors.[205] Of the estimated total available 3 Mtonne fatty acids in the EU, approximately 1.5 Mtonne is produced and directly used in the oleochemical sector and 1.5 Mtonne is traded in the market. Of this, around 0.5 Mtonne is high quality fatty acid which is mostly used for animal feed production (some is also used for biofuel production). The remaining 1 Mtonne of lower quality is used in paper, heat or biofuel production.

Besides the above-mentioned feedstock types, Searle and Malins also estimated the amount of biogenic waste available at 63 million tonnes a year. This is largely comprised of household and similar residues (46 Mtonne), sorting residues (6.9 Mtonne), and common sludges (3.5 Mtonne). The competing uses of biogenic wastes are composting for fertiliser production, backfilling as material used in landscaping or engineering, and incineration for power and heat production.[206]

From this analysis it is clear that bioenergy applications often compete with other sectors that use biomass. Many waste and residue streams have other applications besides bioenergy and could imply that it will become costlier for these other sectors to obtain the same material. Also, the environmental benefits of using waste streams for bioenergy application may in some cases be smaller if other sectors will be forced to use other feedstock with higher greenhouse gas impacts. However, it was not possible to establish the economic or environmental impacts from this competition, because the level of competition and how the market changes can only be understood by complex models. For policy makers, it is important to understand the real potential of each feedstock, and how this may change over time. Low ILUC approaches can help to increase the production of bioenergy crops without intensifying the impacts on other biomass using sectors.

As biorefineries become more prevalent in the EU and technology matures in the coming years, there will be new sectors that increase competition for biomass, such as the bio-based chemicals and bio-based material industries. However, in an integrated biorefinery approach, a biomass feedstock is used most efficiently and converted into a spectrum of valuable products. Power, heat, and biofuels can be synergistically co-produced with food, feed, pharmaceuticals, chemicals, materials, and minerals.[207] Market forces will likely dictate which products are produced in which volumes and how these different sectors will compete.

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[203] These include additives, adhesives, metal working fluids, resins and rubber emulsifiers.
[204] Ecofys 2017, Crude tall oil low ILUC risk assessment, available at https://www.upmbiofuels.com/siteassets/documents/other-publications/ecofys-crude-tall-oil-low-iluc-risk-assessment-report.pdf
[205] Ecofys, 2016, Assessment of fatty acids, confidential report.
[206] S.Y. Searle, C.J. Malins, Waste and residue availability for advanced biofuel production in EU Member States, Biomass and Bioenergy (2016), http://dx.doi.org/10.1016/j.biombioe.2016.01.008
[207] IEA Task 42, Biorefining in a Future BioEconomy, Triennium 2016-2018.

Appendix A. Share of biodegradable fraction of waste

Table 21. Reported information by MS on the share of biodegradable fraction of waste used for energy production

MS	Renewable fraction	Manner used for estimation and any steps taken to improve estimates
Austria	N/A	The share of biodegradable waste in waste is determined based on information from samples for which the geographical scope is to be expanded. No mention of actions to improve the estimation.
Belgium	47.78% (Flanders)	Based on data from the 2006 local waste sorting campaign in Flanders. The method is described in the report “Determination of the renewable share of residual waste” (Vito, April 2009)[2].
	47% (Wallonia)	The share of incinerated waste of the intermunicipal waste mass is estimated based on ICEDD, energy balance 2013.
Bulgaria	N/A	During the reporting period the Methodology for determining the morphological composition of household waste was applied. The methodology has been published on the website of the MOSV [3] and ensures a single approach to determining and estimating the quantity and morphological composition of household waste.
Croatia	28.6%	The basis on which the share of municipal waste is estimated.
Cyprus	N/A	The biomass fraction of specific alternative fuels was determined by analyses carried out by laboratories accredited according to EN ISO/IEC 17025.
Czech Republic	N/A	The proportion of biodegradable municipal waste specified in Decree No 477/2012, on determining the types and parameters of renewable sources supported for electricity, heat or biomethane production, and on the establishment and preservation of documents, is determined on the basis of consultation and information from the IEA, Eurostat, other EU countries, and information from local operators of municipal waste incinerators.
Denmark	55%	This proportion is determined on the basis of a study carried out in 2012. From 1 January 2013 Denmark has decided to include 21 of the largest waste incineration plants in the CO_2 quota adjustment. These plants determine their annual emission of fossil CO_2 by measuring the CO_2 content of the flue gas. Two different methods are used for these measurements. These are a 14C method and a mass balance method (Bioma), which is based on a number of balances set up for the plant. No mention of actions to improve the estimation methods.
Estonia	65%	Estonia has regularly conducted studies on the sorting of mixed municipal waste (the Ministry of the Environment has commissioned such a study every two or three years), which provide a good overview of the share of biodegradable waste and also changes therein. No mention is made on the exact method used for estimating, nor are actions mentioned to improve estimation methods.
Finland	50%	The estimate is based on sampling. A national recommendation on composition analyses was issued to improve the quality of sampling in 2014, and the volume of sampling has increased. A composition database has been set up to record the data with the aim of collating and processing the results of qualitative testing and composition analyses for various types of waste. There is no clear indication of the method used by survey respondents for the estimation of the share.
France	N/A	No information provided.
Germany	50%	This value comes from a study (UBA, 2011 [6]) which examines the waste flows from selected treatment methods in detail. The report further mentions that the methods of determining the biogenic fraction are being constantly improved and tested for practical viability (e.g. C14 method) without clear indication how these improvements are achieved.
Greece	N/A	The energy produced from waste (municipal, industrial etc.) corresponds exclusively to biogas primary production deriving from landfill and sewage sludge biogas plants. Until now, no RDF/SRF are exploited for electricity production in Greece and thus no requirement has arisen to estimate the share for biodegradable waste in the reported figures.
Hungary	~ 57%	The current methodology goes beyond the previous one, as it is not based on an estimate, but on the data transmitted by data providers. In statistical questionnaires, data providers must distinguish between the amounts of renewable and non-renewable waste.
Ireland	N/A	The renewable fraction of waste used in producing energy is calculated in accordance with the standard I.S. EN 15440:2011 "Solid Recovered Fuel, Methods for the Determination of Biomass Content". This standard specifies a number of methodologies that may be used i.e. the selective dissolution method, the manual sorting method and the Carbon 14 method. The data obtained in accordance with the standard may be combined with waste characterization survey data that is demonstrated to the satisfaction of the CRU (administrator of the PSO) to be representative of the waste composition at the generation facility, in order to determine the renewable fraction. Calculations of the renewable fraction must be verified by an independent third party on an annual basis.
Italy	50-51%	Under national law, the incentives for electricity from biodegradable waste are calculated two ways: - Fixed rates for certain categories of waste;

MS	Renewable fraction	Manner used for estimation and any steps taken to improve estimates
		- Analytical determination methods for the remaining waste. The share of electricity generated from renewable sources and eligible for the incentive is set at a fixed rate of 51% of net generation from sorted municipal waste and, under certain conditions, from other specific types of non-municipal waste. This fixed rate (very similar to the share considered for statistical purposes) was set by the legislator following a testing campaign conducted on the municipal waste used by a representative sample of waste-to-energy plants.
Latvia	N/A	The amount of biodegradable waste and residues used for biogas production in Energy Statistics can be obtained by analyzing statistical data on the amount of biodegradable waste recycled in a given year that according to the type of recovery (R3D-Biogas extraction (excluding biogas from waste disposal))is used for deriving biogas in production. No measures were taken during the reporting period to improve or verify the estimates of the share of biodegradable waste in the waste for energy production.
Lithuania	N/A	Economic operations use the Lithuanian Standard LST EN 15440:2011 'Solid recovered fuels - Method for the determination of biomass content'. At least four times per year tests are to be done. No mention is made on the exact method used, nor are any actions mentioned to improve this estimation.
Luxembourg	N/A	The different shares in wet waste are determined on the basis of on-site surveys (from 1992, 1994, 2001, 2004/2005 and 2009) and extrapolated to the total quantity of waste. The total quantity of wet waste is then converted into dry waste using wet waste coefficients. The quantity of energy is then calculated on the basis of the calorific value of the waste category concerned. The biodegradable carbon content is used to calculate the biodegradable fraction of the waste category in question. The renewable energy share of the waste, and consequently the renewable share of electricity production, is thus determined. This is the same method as applied in the previous report.
Malta	100%	Malta's current waste-to-energy plants are based on an anaerobic digestion process and thus all processed waste is biodegradable. Shares of biodegradable content per waste stream are provided, e.g. mixed MSW 66%. No exact method for estimation of the share is mentioned, nor are actions to improve the estimation.
Netherlands	54%	The method of estimating the share of biodegradable waste in waste used for producing energy is described in the 'Methodology report on the calculation of emissions to air from the sectors Energy, Industry and Waste' (ENINA 2019).[1] The model for the calculation of the share of renewable energy is also used to calculate the emissions from waste incineration plants in the framework of the reports for UNFCCC and the Kyoto Protocol. ENINA 2019 also describes the quality control. The estimate of the share of biodegradable waste is made annually by an independent organisation, the Rijkswaterstaat Environment, using various annual reports. The estimate is based on seven stages. The data from the years of research into the composition of waste in the Netherlands are used to form the basis. The data obtained from that are used to determine the energy and carbon content and associated share of biomass of the waste streams burned in waste incineration plants. The biomass share of energy is then used to calculate a 'flat-rate percentage' of renewable energy for all waste incineration plants in the Netherlands.
Poland	N/A	The share is based on 'direct measurement' by examining the share of biodegradable fractions (defined by harmonised standards for solid recovered fuel) or taking a flat rate value (based on an expert study – no reference provided). No actions are mentioned to improve the estimation.
Portugal	50%	The share is supplied on an annual base by electricity producers. No details on methodology for estimation nor on actions to improve such estimations are provided.
Romania	55-60%	As regards the quantities of biodegradable waste generated in Romania, the National Waste Management Plan lists the quantities of municipal waste generated in Romania in the period 2010-2014 and the composition of this waste. Biodegradable waste accounts for approximately 55-60% of the composition of household waste and waste similar to household waste collected by sanitation operators in the period 2010-2014. The production of energy based on the biodegradable actions in waste was not reported in 2017 and 2018.
Slovakia	50-55%	Renewable fraction is determined directly by companies involved in recovering energy from waste. These data are recorded and sent to the Statistical Office. As regards the incineration of municipal waste, only the biological portion of waste in municipal waste is supported, up to a maximum biodegradable-waste share of 55%. This also corresponds to analyses carried out, in which the share of biodegradable waste has been estimated at 50%. No details on methodology for estimation nor on actions to improve such estimations are provided.
Slovenia	N/A	No information provided.
Spain	N/A	Share of waste comes from Biofuel Statistics published by the Biofuel Certification Entity of the CNMC. As the body responsible for certifying compliance with the biofuel consumption obligation, the ECB obtains data via the SICBIOS IT application. No details on methodology for estimation nor on actions to improve such estimations are provided.
Sweden	52%	This assumption has been made based on an investigation of the composition of waste published in 2017 [4]. A previous study dating from 2008 was updated with new input data

MS	Renewable fraction	Manner used for estimation and any steps taken to improve estimates
		as regards waste composition taking into account available measurement data from seven major waste incineration plants. Two types of methods are mentioned, namely the analyses of solid waste and the analyses of the flue gases formed during incineration. In 2008, it was shown that 60% of the waste was of renewable origin. The reduction since then is primarily explained by changes in the composition of the waste due to an increase in domestic sorting of waste at source and an increase in the proportion of imports.
UK	N/A	Waste with 10% or less of renewable content is regarded non-renewable waste. Fuel Metering and Sampling procedures are put in place by Ofgem[5] for assuring an accurate calculation of the proportion of biodegradable material. The testing and sampling is often done by independent accredited laboratories. Also, there is an audit programme in place with a selection of generation stations. No actions are mentioned to improve the estimation.

[1] https://english.rvo.nl/sites/default/files/2019/05/ENINA%202019-0018.pdf
[2] https://esites.vito.be/sites/reflabos/onderzoeksrapporten/Online%20documenten/rapport_aandeel_hernieuwbaar_maart%202011.pdf
[3] http://www.moew.government.bg/bg/otpaduci/bitovi-otpaduci/
[4] Profu, 2017. Analysis of the renewable energy fraction in waste for combustion. Swedish Energy Agency ref. No 2016-010523.
[5] https://www.ofgem.gov.uk/publications-and-updates/renewables-obligation-fuel-measurement-and-sampling-guidance
[6] UBA, 2011. Nutzung des Potenzials des biogenen Anteils im Abfall zur Energieerzeugung, IAA TU Dresden.

Appendix B. Availability and use of biomass resources

The following tables present the information as provided by the Member States in their Progress Reports ('Table 4 in Question 6').

Table 22. Biomass consumption for heating and electricity based on Table 4 in the Member States Progress Reports in ktoe unless otherwise specified

MS	Domestic vs import	Direct supply of wood biomass from forests		Indirect supply of wood biomass		Energy crops and short rotation trees		Agr by-products / processed residues		Biomass from waste		Others	
		2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
AT	Domestic	1,582	1,602	1,575	1,643	13	13	-	-	180	198	532	518
AT	EU	198	198	1,050	1,084	-	-	-	-	-	-	-	-
AT	Non-EU	-	-	51	51	-	-	-	-	-	-	-	-
BE	Domestic	No information provided											
BE	EU												
BE	Non-EU												
BG	Domestic	4,565,264 m^3	4,357,710 m^3	-	-	256,411 m^3	275,827 m^3	-	-	-	-	-	-
BG	EU	No information on imported biomass provided											
BG	Non-EU												
CY	Domestic	14	16	2	2	0	0	2	2	2	2	9	9
CY	EU	0	0	0	0	0	0	0	0	17	27	0	0
CY	Non-EU	0	0	11	10	0	0	0	0	0	0	0	0
CZ	Domestic	1,791	1,855	1,053	1,082	152	133	541	538	158	153	0	0
CZ	EU	2	2	235	200	0	0	0	0	0	0	0	0
CZ	Non-EU	2	2	7	3	0	0	0	0	0	0	0	0
DK	Domestic	1,002	1,065	251	283	-	-	483	421	468	441	-	-
DK	EU	149	159	828	797	-	-	-	-	53	64	-	-
DK	Non-EU	44	53	486	468	-	-	-	-	-	-	-	-
EE	Domestic	5,600,000 m^3	,.670,000 m^3	2,200,000 m^3	2,234,000 m^3	-	-	-	-	-	-	-	-
EE	EU	No information on imported biomass provided											
EE	Non-EU												
FI	Domestic	2,704	2,718	5,962	6,232	-	-	-	-	327	349	-	-
FI	EU	0	0	4	8	-	-	-	-	-	-	-	-
FI	Non-EU	0	1	55	58	-	-	-	-	-	-	-	-
FR	Domestic	-	-	-	-	-	-	-	-	-	-	-	-
FR	EU	-	-	-	-	-	-	-	-	-	-	-	-
FR	Non-EU	-	-	-	-	-	-	-	-	-	-	-	-
DE	Domestic	6,165	5,947	2,666	2,590	-	-	1,160	1,013	6,690	6,677	154	150
DE	EU	108	104	404	352	-	-	0	0	331	288	24	21
DE	Non-EU	161	152	130	118	-	-	0	0	10	4	1	0
EL	Domestic	180	176	16	17	-	-	604	577	0	0	0	8
EL	EU	40	40	18	13	-	-	-	-	-	-	-	-
EL	Non-EU	2	1	11	8	-	-	-	-	-	-	0	1
HR	Domestic	1,208	1,110	305	355	-	-	-	-	14	7	64	74
HR	EU	1	5	10	13	-	-	-	-	-	-	-	-
HR	Non-EU	12	10	13	16	-	-	-	-	-	-	-	-
HU	Domestic	897	894	10	8	-	-	-	-	411	161	-	-
HU	EU	5	6	22	15	-	-	-	-	n/a	n/a	-	-
HU	Non-EU	48	41	17	17	-	-	-	-	n/a	n/a	-	-
IE	Domestic	56	58	80	-	3	-	23	23	158	201	12	12
IE	EU	1	2	0	0	-	-	-	-	-	-	-	-
IE	Non-EU	0	0	0	0	-	-	17	0	-	-	12	12
IT	Domestic	6,094	5,468	693	543	1,341	1,336	1,113	1,126	1,558	1,598	-	-
IT	EU	234	257	700	834	75	77	-	-	-	1	-	-
IT	Non-EU	128	122	152	230	579	519	-	-	2	-	-	-
LV	Domestic	1,199	1,435	833	1,006	-	-	6	5	11	10	83	78
LV	Import[1]	89	119	34	57	-	-	-	3	0	0	-	-
LT	Domestic	929,600 m^3	886,100 m^3	-	-	-	-	-	-	11,640	10,089	-	-
LT	EU	No information on imported biomass provided											
LT	Non-EU												
LU	Domestic	38,408 m^3	40,768 m^3	-	-	13,709 tTM	15,564 tTM	-	-	-	-	0	0
LU	EU	5,483 t	4,877 t	-	-	-	-	-	-	-	-	-	-
LU	Non-EU	-	-	-	-	-	-	-	-	-	-	-	-
MT	Domestic	-	-	-	-	-	-	4,793 t	4,397 t	1	1	-	-
MT	EU	0	0	1	1	-	-	-	-	-	-	-	-
MT	Non-EU	0	0	1	1	-	-	-	-	-	-	-	-
NL	Domestic	322	322	656	743	3	4	437	371	1,319	1,265	0	0
NL	EU	No information on imported biomass provided											
NL	Non-EU												
PL	Domestic	4,797	4,796	-	-	29	43	283	196	905	845	92	98
PL	EU	49	52	-	-	-	-	-	-	-	-	-	-
PL	Non-EU	347	472	-	-	-	-	-	-	-	-	-	-
PT	Domestic	1,093	1,144	1,274	1,256	209	194	-	-	-	-	77	75
PT	EU	-	-	24	24	-	-	-	-	-	-	-	-
PT	Non-EU	-	-	-	-	-	-	-	-	-	-	-	-
RO	Domestic	-	-	3,447	3,506	3	3	-	-	-	-	0	0
RO	EU	-	-	0	0	0	0	-	-	-	-	0	0
RO	Non-EU	-	-	0	0	0	0	-	-	-	-	0	0
SK	Domestic	323	320	525	522	102	99	0	0	18	17	-	-
SK	EU	2	2	0	0	0	0	0	0	0	0	-	-

MS	Domestic vs import	Direct supply of wood biomass from forests		Indirect supply of wood biomass		Energy crops and short rotation trees		Agr by-products / processed residues		Biomass from waste		Others	
SK	Non-EU	3	3	12	11	0	0	0	0	0	0	-	-
SI	Domestic	No information provided											
SI	EU												
SI	Non-EU												
ES	Domestic	1,618	1,606	1,864	1,851	-	-	1,831	1,818	668	674	-	-
ES	EU	No information on imported biomass provided											
ES	Non-EU												
SE	Domestic	2,190	2,020	6,837	6,532	13	13	66	60	707	625	707	625
SE	EU	9	7	128	141	-	-	24	30	97	100	-	-
SE	Non-EU	6	2	342	642	-	-	15	30	97	100	-	-
UK	Domestic	No information provided											
UK	EU												
UK	Non-EU												

[1] The Member State Progress Report of Latvia doesn't distinguish between imports from within and outside of the EU

Table 23. Biomass consumption for transport based on Table 4 in the Member States Progress Reports

MS	Domestic vs import	Common arable crops for biofuels		Energy crops		Others	
		2017	2018	2017	2018	2017	2018
AT	Domestic	38	43	13	13	-	-
AT	EU	359	405	-	-	-	-
AT	Non-EU	59	57	-	-	-	-
BE	Domestic	No information provided					
BE	EU						
BE	Non-EU						
BG	Domestic	No information provided					
BG	EU						
BG	Non-EU						
CY	Domestic	0	0	0	0	0	0
CY	EU	0	0	0	0	9	9
CY	Non-EU	0	0	0	0	0	0
CZ	Domestic	-	-	0	0	0	0
CZ	EU	-	-	0	0	0	0
CZ	Non-EU	-	-	0	0	0	0
DK	Domestic	No information provided					
DK	EU						
DK	Non-EU						
EE	Domestic	No information provided					
EE	EU						
EE	Non-EU						
FI	Domestic	No information provided					
FI	EU						
FI	Non-EU						
FR	Domestic	No information provided					
FR	EU						
FR	Non-EU						
DE	Domestic	482	398	0	0	190	230
DE	EU	772	712	0	0	362	408
DE	Non-EU	652	732	0	0	242	388
EL	Domestic	100	79	-	-	31	43
EL	EU	27	17	-	-	0	0
EL	Non-EU	7	19	-	-	-	0
HR	Domestic	0.4	0.3	-	-	-	-
HR	EU	29.2	0.2	-	-	-	-
HR	Non-EU	0.0	-	-	-	-	-
HU	Domestic	288,000	368,000	-	-	-	-
HU	EU	-	-	-	-	-	-
HU	Non-EU	-	-	-	-	-	-
IE	Domestic	0	0	-	-	17	18
IE	EU	0	0	-	-	0	0
IE	Non-EU	0	0	-	-	0	0
IT	Domestic	0	0	-	-	81	83
IT	EU	18	13	-	-	40	47
IT	Non-EU	275	64	-	-	82	202
LV	Domestic	-	-	-	-	53[1]	84[1]
LV	Import[2]	-	-	-	-	10	26
LT	Domestic	119	151	-	-	-	-
LT	EU	No information provided					
LT	Non-EU						
LU	Domestic	n/a	n/a	-	-	-	-
LU	EU	-	-	-	-	-	-
LU	Non-EU	-	-	-	-	-	-
MT	Domestic	-	-	-	-	-	-
MT	EU	-	-	-	-	-	-
MT	Non-EU	-	-	-	-	-	-
NL	Domestic	No information provided					
NL	EU						
NL	Non-EU						
PL	Domestic[3]	1323716 kt	1308425 kt	-	-	408682 kt	426035 kt
PL	EU	No information provided					
PL	Non-EU						
PT	Domestic	-	-	-	-	-	-
PT	EU	-	-	-	-	-	-

MS	Domestic vs import	Common arable crops for biofuels		Energy crops		Others	
PT	Non-EU	-	-	-	-	-	-
RO	Domestic	340	386	-	-	-	-
RO	EU	0	0	-	-	-	-
RO	Non-EU	0	0	-	-	-	-
SK	Domestic	73	72	0	0	-	-
SK	EU	n/a	n/a	0	0	-	-
SK	Non-EU	n/a	n/a	0	0	-	-
SI	Domestic	No information provided					
SI	EU						
SI	Non-EU						
ES	Domestic	No information provided					
ES	EU						
ES	Non-EU						
SE	Domestic	30	40	-	-	165	156
SE	EU	277	286	-	-	420	486
SE	Non-EU	73	109	-	-	709	719
UK	Domestic	No information provided					
UK	EU						
UK	Non-EU						

[1] The Member State Progress Report of Latvia doesn't provide information on feedstock. These numbers refer to primary energy of raw materials for the total of biodiesel and bioethanol.
[2] The Member State Progress Report of Latvia doesn't distinguish between imports from within and outside of the EU.
[3] Numbers refer to amount of basic feedstocks of agricultural origin and products of feedstock processing used for production of esters and bioethanol in kilotonnes. Neither the energy content nor the origin are specified.

Appendix C. Local environmental impacts related to biofuels

In the following section, the local environmental impacts for the main crop-country combinations supplying feedstock for biofuels consumed in the EU are analysed. Crops cultivated for bioethanol within the EU consist mainly of wheat, maize, and sugar beet. For biodiesel, rapeseed is the main cultivated crop. Non-EU biodiesel feedstock production is primarily produced through soybean cultivation in Argentina and oil palm cultivation in Malaysia and Indonesia.

The local environmental impacts assessment differs between the crop-country combinations. For the crops produced within the EU (section EU biofuel crops) the analysis is based on the developments of the environmental status as described by the EEA and Eurostat. For the assessment of the non-EU crop-country combinations (section non-EU biofuel crops) the approach is based on reviews of scientific literature.

A challenge in the analysis of local environmental impacts of biofuels is the lack of transparency in agricultural supply chains, making it difficult to trace the origin of the feedstock. To determine the actual local environmental impact of a biofuel crop, site-specific data is essential as impacts will vary widely between countries, farms, management practices, and fields.

Another question specific to the EU is whether cultivation systems and management practices used for European biofuel crop production differ significantly from crop cultivation for food production. Feedstock for biofuels consumed in the EU must adhere to the sustainability criteria from the 2009 Renewable Energy Directive. To ensure that the biofuels meet the criteria of the RED, biofuels need to be validated by national verification systems or by one of the 15 voluntary schemes approved by the EC. However, it is difficult to fully evaluate the effect of these schemes, as environmental impact criteria differ between schemes and total certified biofuel volumes lack transparency[208].

EU biofuel crops – rapeseed, wheat, maize and sugar beet

Over half of the feedstock for crop-based biofuels is grown in the EU. As described in the Renewable Energy Directive, all EU Member States report every two years on their national renewable energy developments including the impact on biodiversity and air, soil and water quality (as described in section 5.4.1). Most Member States indicate that within their country there is either limited domestic biofuel feedstock production compared to all agricultural production, or that all their agricultural production is regulated with respect to environmental impacts. Therefore, impacts of biofuel crop production are expected to be the same as those of other crop production.

The most common types of feedstock grown in the EU for biofuels are rapeseed, wheat, maize, and sugar beet. Many of the environmental impacts of the main biofuel crop production are generic to agriculture, however some distinct impacts can be related to the production of rapeseed, wheat, maize and sugar beet in Europe. The section below provides an overview and analysis of the current state and outlook of agriculture in the EU and provides specific insights for biofuel feedstocks.

Background and current state

In Europe grass- and cropland make up 43% of the landcover[209]. Farming practices and structures differ significantly across and within the EU Member States, reflecting highly diverse biogeographic, economic and social conditions. The EU's 7th Environment Action Programme[210] set out the 2050 vision of "living well, within the limits of our planet", the EU is committed to multiple policy objectives

[208] ECA, 2016. The EU system for the certification of sustainable biofuels. Special Report No 18, 2016. European Court of Auditors.
[209] FAOstat, 2018
[210] EAP, 2014. General Union environment action programme to 2020. EU Publication by DG ENV.

focussing on the environmental outcomes of agricultural activities. These include the objectives of the EU nature legislation, the 2020 biodiversity strategy, the National Emission Ceilings Directive on air pollution, the Effort Sharing Regulation on greenhouse gas (GHG) emissions, the LULUCF Regulation on land-use change and forestry and the Water Framework Directive and Nitrates Directive on water quality.

Water quality

The ecological status and quality of surface water ecosystems in Europe are assessed under the Water Framework Directive[211]. Currently, 40% of Europe's 111.000 water bodies achieve good ecological status[212]. One of the main environmental pressures on water quality in Europe is diffuse pollution, affecting 38% of the surface water bodies and 35% of the groundwater bodies. Run-off and leaching of nitrogen-based fertilisers used on agricultural land have been identified as a primary cause[213] . Excess nitrogen discharges to soil, water and air result in systemic environmental issues such as eutrophication in which a water body becomes overly enriched with nutrients and minerals, resulting in toxicity, oxygen depletion, decreased biodiversity and changes in species composition. Between 2000 and 2015 agricultural nitrogen surplus decreased by 18% in the EU[212]. However, the overall fertiliser application remains high. Under the Nitrates Directive, Member States are implementing multiple measures, many of which are compulsory in nitrate vulnerable zones, to reduce the impact and input of nitrogen. Measures include the management of nutrients on farm-level, standards for the timing of fertiliser application, appropriate tillage techniques, the use of nitrogen-fixing catch crops, crop rotation, and uncultivated buffer strips along rivers and streams[214]. Risks related to pesticide and nutrient leaching are emphasized especially for maize, rapeseed and sugar beet. These crops have a high fertiliser demand and leaching risk due to soil erosion, harvesting residues, or water demand[215]. An important factor to take into account here is the impact per energy-unit of biofuel, e.g. maize and wheat are comparatively low yielding meaning that the impact can still be quite high.

40% of Europe's water abstraction can be attributed to agricultural activities. Especially in southern Europe, this figure can exceed 80% in the summer months. Water scarcity arises as a consequence of the water demand and through reduced precipitation (e.g. rain, snow, fog). Between 2005 and 2016, crop production in Europe became 12% less water intensive. Due to more efficient irrigation techniques, a clear trend for absolute decoupling of total water input and gross value added in crop production has been observed. The total water input to crops decreased from 5 m^3 to 4.4 m^3 for each unit of gross value added generated[216]. However, water scarcity is expected to become increasingly frequent and widespread in Europe in response to a changing climate, making this an important environmental pressure[213].

Crop based bioethanol and biodiesel have by far the largest water footprint of the EU renewable energy sources, partly due to their vast consumption of soil moisture[217]. Especially in southern Europe water consumption is linked to agriculture, where crops such as maize and sugar beet are often irrigated[218]. Rapeseed and wheat have less impact on water abstraction, as these crops are often dependent on seasonal patterns of precipitation. Water use improvements can be obtained by more efficient irrigation methods or through more resilient crop selection.

[211] EU Water Framework Directive (WFD), 2000. EU Publication by DG ENV.
[212] EEA, 2018. Chemicals in European waters — knowledge developments.
[213] EEA, 2019. The European environment – state and outlook 2020.
[214] EU Nitrates Directive, 1991. Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources. EU publication.
[215] EU Biofuels baseline 2008, 2011.
[216] EEA, 2019. Water intensity of crop production in Europe.
[217] JRC newsletter, 2019. Water footprint of EU energy consumption: 1,301 litres per person per day. https://ec.europa.eu/jrc/en/news/water-footprint-eu-energy-consumption
[218] Eurostat, 2018. Agri-environmental indicator - irrigation.

Soil quality

The 2018 mapping of Europe's land cover assessed in the Corine Land Cover data sets[219], indicates that the proportion of Europe's main land cover types is relatively stable. Around 9% of agricultural land is part of Natura 2000 sites[220] and around 30% is classified as high nature value farmland[221]. However, the high demand for agricultural output and trend towards intensification leads to various pressures on the land and soil, such as soil erosion, soil compaction, soil organic carbon loss and soil biodiversity decrease, creating cumulative impacts on ecosystems.

Conversion of grasslands to croplands and increased fertilisation rates, create environmental pressures on erosion control, storage of soil carbon and soil biodiversity. Grasslands are one of the most species-rich vegetation types[222], conversing these lands lead to negative consequences for pollinators, other insects and birds. Erosion of soils is described by the loss of soil by water or wind, or through harvest losses. Soil adhering to harvested root-crops (such as sugar beet and potato) contributes to significant soil removal. Panagos et al. (2019) estimate that 4.2 million hectares of root-crops contribute to 14.7 million tonnes of soil loss[223]. Soil erosion leads to loss of productivity and soil function, and potential leakage of soil material and pollutants into water systems. Soil erosion is particularly for maize and sugar beet deemed a high risk, with significant soil removal through harvesting losses for sugar beets and soil erosion through wind for maize as a result of extensive periods where soils are left bare. Crops grown over winter such as winter-wheat and winter-rapeseed provide good crop cover, thereby reducing erosion risks.

A precursor of erosion is soil compaction, resulting from heavy machinery use on agricultural lands, causing increased soil density and reduction of soil structure and porosity. This has a negative effect on root penetration and the habitat of soil organisms, lowering crop yields and water retention capacity[224]. About 23% of soils in the EU are estimated to have critically high densities in their subsoils[225]. In some Member States guidelines exist on access to wet soils, however on EU level no regulations are in places. Especially sugar beet is accounted as a susceptible crop to soil compaction[226].

Soil organic carbon (SOC) is one of the primary sources of energy in the food pyramid. Losses of carbon through erosion, climate change and drainage impact the ecosystem and reduce biodiversity[227]. Decomposition of organic material is the fundamental process for building SOC pools which are important for the nutrient cycle and retention. SOC in mineral cropland soils in the EU have been broadly stable over time the past years, however much lower compared to SOC in other land cover categories. Mean SOC for permanent crops is 16.4 g/kg, compared to 90.4 g/kg in natural vegetation and 43.8 g/kg in permanent grassland[228]. The dynamics of SOC vary according to land use and specific management practices. SOC loss in wheat, maize and rapeseed can be partly prevented by the retention of crop residues on the agricultural soils (Stella et al., 2019). The RED II states additional sustainability criteria, which add a limit to crop residue extraction to ensure that soil quality and soil carbon are maintained or improved[229].

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[219] Corine Land Cover inventory, 2018. https://land.copernicus.eu/pan-european/corine-land-cover
[220] EU agricultural outlook for agricultural markets and income 2017-2030, European Commission. EU publication by DG AGRI.
[221] Paracchini et al., 2008. High nature value farmland in Europe — an estimate of the distribution patterns on the basis of land cover and biodiversity data. EUR - Scientific and Technical Research Report
[222] Silva et al., 2008. LIFE and Europe's grasslands: restoring a forgotten habitat. Office for Official Publications of the European Communities, Luxembourg.
[223] Panagos, et al., 2019. 'Soil loss due to crop harvesting in the European Union: a first estimation of an underrated geomorphic process', Science of The Total Environment 664, pp. 487-498
[224] Brus and van den Akker, 2018. 'How serious a problem is subsoil compaction in the Netherlands? A survey based on probability sampling', SOIL 4(1), pp. 37-45
[225] Schjønning, et al., 2015. 'Soil compaction', in: Soil threats in Europe: status, methods, drivers and effects on ecosystem services. RECARE project, JRC Technical Report, Joint Research Centre, pp. 92-101.
[226] Marinello et al., 2017. Traffic effects on soil compaction and sugar beet (Beta vulgaris L.) taproot quality parameters. Spanish Journal of Agricultural Research, Volume 15, Issue 1, e0201
[227] Stolte et al., 2016. Soil threats in Europe: status, methods, drivers and effects on ecosystem services. RECARE project, JRC Technical Report
[228] Hiederer, 2018. Data evaluation of LUCAS soil component laboratory data for soil organic carbon, JRC Technical Report, Luxembourg
[229] RED II, article 29.2.

Several national studies done on pesticide residues in agricultural soils, indicate that contamination of soils is widespread in Europe[230, 231]. Concerns are raised on the accumulation of pesticide residues and their potential release mechanisms for example through acidification and wind erosion[230]. Due to high levels of pesticide use, leakage is deemed the most problematic for rapeseed and maize.

Sustainable management can improve the many potential positive environmental impacts of land and soils. Soil can function as a carbon sink, a filter for water and nutrients, and a support system for biodiversity. Currently, there is no European legislation that focusses exclusively on soil, the lack thereof can have a potentially negative effect on soil protection in the EU.

Air quality

Air quality can have a direct effect on fauna and vegetation by affecting the soil and water quality. Intensively managed agricultural areas contribute to air pollution mainly via the spreading of animal manure or agro-chemicals on fields with no or little vegetation cover. This process increases the level of particulate matter in the air (PM). Precipitation can then lead to the atmospheric deposition of these nitrate and ammonium compounds, exceeding the critical load for eutrophication and disturbing terrestrial and aquatic ecosystems. Excessive amounts of the nutrient nitrogen can lead to changes in species diversity and invasion of new species.

At the EU level, air pollution is a well-established environmental policy area, setting emission standards for the agricultural sector (e.g. Clean Air for Europe Programme, Ambient Air Quality Directives, Nitrate Directive). When legal limits for ambient concentrations of air pollutants are exceeded, Member States are obliged to implement reduction plans and measures. The cooperative program for monitoring and evaluation of the long-range transmission of air pollutants in Europe[232] shows that in 2016 lower emissions of air pollutants have contributed to fewer exceedances of acidification and eutrophication limits. However, in 2016, the critical loads for eutrophication were still exceeded in over 62% of the European ecosystem area. Air pollution risks are high for rapeseed, sugar beet, maize and wheat in the EU as the cultivation of these crops requires fertilization of the soil.

Non-EU biofuel crops – palm oil and soy

This section provides an overview of local environmental impacts related to the production of EU biofuels from palm oil cultivation in Indonesia and Malaysia, and soy cultivation in Argentina.

Palm oil

Palm fruit oil (*Elaeis guineensis* Jacq.) is a tropical oil. The ideal growing conditions for palm oil are found only within 10 degrees north or south of the equator, on the continents of Asia, Africa and South America. The common denominator of these areas is the vast areas of tropical rainforest rich in biodiversity they contain. In the recent decades the demand for edible vegetable oils has grown strongly and palm oil plantations have expanded rapidly in number and size to meet the global demand. This analysis will focus on the two countries with the largest production of palm oil; Indonesia and Malaysia. Palm fruit oil from these two countries is the feedstock for respectively 15% and 7% of all biodiesel consumed in the EU and covers 99% of all palm fruit oil used as feedstock for biodiesel consumed in the EU.

Palm oil used for biofuels in the EU needs to adhere to the sustainability criteria in the Renewable Energy Directive. The Renewable Energy Directive forbids the use of feedstocks from deforested

[230] Silva et al., 2019. 'Pesticide residues in European agricultural soils – a hidden reality unfolded', Science of the Total Environment 653, pp. 1532-1545
[231] Swartjes et al., 2016. Appraisal of measures for the reduction of pesticide load in groundwater as drinking water resource, RIVM, Netherlands
[232] EMEP, 2018. Transboundary particulate matter, photo-oxidants, acidifying and eutrophying components, Status Report No 1/2018, Cooperative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe.

lands (cut-off date 1st of January 2008), therefore recent deforestation can't be directly linked to biofuels used in the EU. Additional restrictions have been put on biofuels counting towards the RES targets in the REDII for the time period 2021-2030. The Directive includes a phase-out of all "high ILUC risk" feedstock by 2030, and no expansion of these feedstocks beyond their 2019 levels[233] unless this feedstock is certified as low ILUC risk. Currently, palm oil falls in this category of high ILUC risk feedstock and this could result in a decline of palm oil biodiesel consumption in Europe towards 2030. In the beginning of June 2020, Indonesia raised a complaint on the REDII, stating that it discriminates against biofuels from palm oil. They asked the dispute settlement body of the World Trade Organization (WTO) to establish a panel to examine the EU REDII on this point[234].

The analysis in this section will focus on environmental impacts related to existing palm oil plantations. It should be noted that tracking of palm oil sources for biofuel production is still challenging, with a lack of transparency of the supply chains. Therefore, standard practices and common environmental risks in palm oil production in Indonesia and Malaysia will be assessed.

However, it should be noted that deforestation of rainforests through the development of new palm oil plantations and expansion of smallholder farms remains a serious concern as general palm oil demand is still expected to grow in the coming years. The removal of acres of rainforest threaten the rich biodiversity in these elaborate ecosystems and releases carbon into the atmosphere. Soil erosion is a big problem, when the rainforest root structure is removed and nutrient-rich soil washes away. Leading to increased use of fertilizers and pesticides, adding to the pressure on the soil, water, and air quality. A simple shift from palm oil to other crops is not deemed a solution as palm oil produces up to nine times more oil per unit area than other major oil crops. Shifting to other crops could result in diminished efforts to produce palm oil sustainably, and an increase in land used for producing other oils (mostly soy, sunflower and rapeseed) shifting environmental impacts to regions where those oils are produced[235].

Water quality

Water and soil impacts are often closely interconnected, with soil problems often leading to water problems. Several water quality risks are related to palm oil production in Indonesia and Malaysia. An analysis on water quality impacts through soil erosion and leaching of nutrients and organic matter can be found in the paragraph below.

The eastern part of Malaysia is affected by the monsoon between mid-October and the end of March every year. During the monsoon period, rainwater can wash off soil and debris from the land into the rivers. Oil palm plantations make up 77% of agricultural land in Malaysia, therefore a large part of river pollution in Malaysia is caused by palm oil plantations. Lack of fertilizing regulations in Malaysia may cause severe environmental damage and exposure of toxic chemicals to the surrounding[236].

Pollution of soil and water caused by wastewater is another major environmental impact. In Malaysia and especially Indonesia, water quality is in many places poor due to several different causes, among these oil palm cultivation and palm oil processing[237]. A by-product of palm oil processing is Palm Oil Mill Effluent (POME), an oily wastewater consisting of various suspended components. A palm oil mill generates 2.5 metric tons of effluent for every metric ton of palm oil it produces. POME is often

[233] EEAS, 2018. Palm Oil: Outcome of the Trilogue of the EU's Renewable Energy Directive (RED II) - EEAS - European External Action Service - European Commission. European External Action Service.
[234] Argus, 15 June 2020. Indonesia's palm oil dispute with EU set to continue. https://www.argusmedia.com/en/news/2114306-indonesias-palm-oil-dispute-with-eu-set-to-continue
[235] Meijaard et al., 2018. Oil palm and biodiversity. A situation analysis by the IUCN Oil Palm Task Force. IUCN Oil Palm Task Force Gland, Switzerland: IUCN.
[236] Che Nadzi et al., 2019. Malaysian Journal of Fundamental and Applied Sciences Vol. 15, No. 1, 85-87
[237] Badan Pusat Statistik, 2018. Statistical yearbook of Indonesia 2017. Badan Pusat Statistik, Jakarta.

discarded in disposal ponds, resulting in the leaching of contaminants that can pollute the soil, and surface- and groundwater affecting biodiversity and human health[238, 239].

POME is considered as the main source of water pollution in Malaysia due to the high biochemical oxygen demand (BOD) and chemical oxygen demand (COD) that causes a reduction of the biodiversity and ability of aquatic ecosystem. Furthermore, the damages to the river cannot be undone easily. Since POME is generated in huge amounts at a time, it is very difficult to manage, and the treatment of this wastewater is expensive. Consequently, the cheapest and easiest way for this wastewater disposal that have been practiced in Malaysia is by discharging the treated POME to the nearby river or stream. However, even treated POME still poses negative effects on the environment[240].

In Malaysia, most industries are able to meet current BOD emission standards of 100 mg/l[241] or the even stricter standards of 20mg/l applied to mills in Malaysian Borneo. These strict standards are in the process of becoming the nation-wide standard[242]. Most oil mills in Indonesia do not comply with discharge limits even though these are less strict than in Malaysia.

Currently, promising research is done on wetland treatment systems using phytoremediation to clean the wastewater. Phytoremediation is one of the environmental-friendly and cost-effective systems, in which plants remove, transfer, stabilize, and/or destroy contaminants in the soil and groundwater. POME can be a source of nutrients for specific plants, increasing growth and creating a potential for biofuel production[240].

Soil quality

Soil quality decline is prevalent in palm oil cultivation in Indonesia and Malaysia and can be impacted by multiple stressors. Under the Renewable Energy Directive, a couple of these impacts are mitigated, such as biodiversity loss through deforestation, soil organic carbon (SOC) losses and soil stability losses related to land use change of especially peatlands.

Soil erosion and sedimentation are major issues in Indonesia and Malaysia and have a big impact on pollution and water quality. High soil erosion rate often leads to river constriction, increased flooding, threatened aquatic habitats, leaching of nutrients and organic matter and silt deposits in rivers and ports[243]. Levels of soil erosion differ between plantations and the season, and depend on the tree arrangements, steepness of the slopes and soil management practices. Eroded areas require more fertilizer and other inputs, including repair of roads and other infrastructure[239]. Erosion rates in matured oil palm plantations in Malaysia range from 7.7 to 14.0 t/ha/yr, soil erosion rates in Indonesia are deemed similar. Cover crops or understory vegetation have shown that they could play a big potential role in mitigating soil erosion and increasing soil biodiversity[243,244].

Soil biodiversity plays a large part in the ecosystem functions, through nutrient cycling, soil carbon sequestration and nutrient uptake by plants, that help maintain soil sustainability. Understory vegetation management varies between plantations, but complete removal by using herbicides (such as paraquat, glufosinate ammonium, and glyphosphate) and weeding is common. Extensive use of herbicides has been related to increased water pollution, threatening ecosystems and impacting human health. Reduction in herbicide use and a greater coverage of understory vegetation has been

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[238] Rusmawarni, 2020. Mathematical modelling of total suspended solid removal from pome via modified electrocoagulation. Journal of Critical Reviews, 7 (8), 67-71.
[239] Wordwilfe.org, Sustainable Agriculture – Palm oil. WWF.
[240] Osman et al., 2020. The effect of Palm Oil Mill Effluent Final Discharge on the Characteristics of Pennisetum purpureum. Sci Rep 10, 6613
[241] Bello and Raman, 2017. Trend and current practices of palm oil mill effluent polishing: Application of advanced oxidation processes and their future perspectives. J. Environ. Manage. 198, 170–182
[242] Tabassum et al., 2015. An integrated method for palm oil mill effluent (POME) treatment for achieving zero liquid discharge - a pilot study. Journal of Cleaner Production 95, 148–155.
[243] Sahat et al., 2016. IOP Conference Series: Materials Science and Engineering. 136
[244] Ashton-Butt et al., 2018. Understory Vegetation in Oil Palm Plantations Benefits Soil Biodiversity and Decomposition Rates. Frontiers in Forests and Global Change.

related to improved avian- and invertebrate biodiversity[245]. Understory vegetation does not seem to have a negative effect on palm oil yield. It could even increase the yield by improving soil quality and lowering operational costs for plantation owners[244, 246].

Another aspect influencing soil quality is compaction, as plantations become bigger the size and weight of machinery used also increases. Various machines have been introduced to reduce labour reliance, as well as to improve productivity. However, mechanised field operations could contribute to gradual degradation of soil's physical properties leading to detrimental effects on crop productivity[247]. Furthermore, soil compaction is associated with a higher risk on floods and droughts as water infiltration capacity becomes lower[248].

Air quality

The main air quality impacts related to palm oil cultivation in Indonesia and Malaysia, come from haze related to burning as land preparation, agrochemical application and processing emissions in the form of soot and dust.

The haze from fire as a land preparation will be mitigated mostly by adherence to the sustainability criteria as stated in the Renewable Energy Directive. However, haze continues to affect the Southeast Asian region and causes significant deterioration in air quality. Currently, it is difficult to determine exactly where the fires originate. The highly voluntary nature of reporting in Indonesia could perhaps explain the poor environmental management performance of plantation companies that has led to the haze problem. Abdullah et al. (2020) discovered that Malaysian companies provided slightly better disclosures compared to Indonesian companies, perhaps due to a better voluntary disclosure environment and increased environmental awareness among Malaysian communities. In Indonesia stakeholders often show no positive response to accountability[249].

Besides the contamination of soils and pollution of surface and ground water as described under the section water quality, POME can also have a negative effect on air quality. POME is typically released into open-air holding ponds for remediation, thereby releasing carbon dioxide, methane, and hydrogen sulphide, all of which have a negative effect on the climate[250]. Palm oil mills that produce palm oil for EU biofuel are obligated to have a methane capture system in place.

Biodiversity

The tropical areas suitable for palm oil plantations are very rich in biodiversity. Land use change from tropical rainforests and other species-rich habitats to oil plantations may therefore result in high levels of biodiversity loss in Indonesia and Malaysia. Most impacts on biodiversity due to the EU biofuel demand will only be indirect displacement effects, as the Renewable Energy Directive sustainability criteria exclude many of the biodiversity risks related to direct land use change. Most certificates (RSPO and ISCC) do not only cover biodiversity impacts resulting from the planning and development phase, but also cover impacts from cultivation and processing activities. However, all the impacts described under soil-, water-, and air quality also have an effect on the soil-, aquatic- and terrestrial biodiversity. Currently biodiversity in Indonesia and Malaysia is still under a lot of pressure[235].

Management practices in existing plantations can contribute to biodiversity restoration. Historically elephants were found in large numbers throughout the forests of Malaysia. However, over the past 100 years elephant numbers have been dropping fast due to habitat fragmentation by plantation development and human-elephant conflicts. Currently, the WWF, together with the Sabah government

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[245] Tohiran et al., 2017. Targeted cattle grazing as an alternative to herbicides for controlling weeds in bird-friendly oil palm plantations. Agron. Sustain. Dev
[246] University of Göttingen, 2019. Palm oil: Less fertilizer and no herbicide but same yield? https://phys.org/news/2019-11-palm-oil-fertilizer-herbicide-yield.html
[247] Zuraidah et al., 2017. Does soil compaction affect oil palm standing biomass? Journal of oil palm research 29 (3). 352-357.
[248] Dislich et al., 2017. A review of the ecosystem functions in oil palm plantations, using forests as a reference system. Biological Reviews 92, 1539–1569
[249] Abdullah et al., 2020. The Southeast Asian haze: The quality of environmental disclosures and firm performance. Journal of Cleaner Production, 246.
[250] Febijanto, 2020. IOP Conference Series: Materials Science and Engineering. 742

and agricultural companies, are partnering to enable a wildlife corridor through a Sabah government-supported palm oil plantation to connect the Silabukan Protection Forest Reserve and the Tabin Wildlife Reserve[251]. The WWF will also support planting native vegetation to restore riverside habitat to attract elephants and species, such as orangutans and gibbons. The long-term aim of the WWF is to foster peaceful coexistence between wildlife and the plantation industry through solutions that benefit both. In the future, as long as further deforestation is limited, it should be possible for Malaysia to maintain a healthy elephant population on both the Peninsula and in Borneo[252].

A key requirement for oil palm plantations to be certified under the RSPO certification scheme, is that the plantations must protect areas of natural forest within their land. Fleiss et al. (2020) found that patches of protected forest play an important role in helping to conserve endangered species including hornbill birds and dipterocarp trees. Furthermore, the same study revealed that plantations, where a tenth of the land is protected as natural forest, store up to 20% more carbon than plantations with no protected forest[253]. It can be noted that a growing body of literature exists on the impact of management practices on biodiversity and the potential mitigation methods in existing palm oil plantations.

Soy

Soybean from Argentina is among the largest import streams of biodiesel feedstock for the EU, with 9% of all biodiesel consumed in the EU based on Argentinian soybeans. Soy cultivation was introduced to Argentina around the 1970s, instigating a gradual but rapid switch from traditional cattle rearing to the farming of soy. The Argentine agricultural sector has always been export-focused and the increasing international demand for agricultural commodities has promoted a process of agricultural intensification[254]. Agricultural intensification has had multiple positive and negative effects on not only the economy and Argentina's development, but also on the environment[255].

Argentina is one of the biggest biodiesel exporters and the number one supplier of soybean oil. Last year, Argentine's global biodiesel exports amounted to around 1 million tonnes worth $775 million, with the European Union as one of the biggest importers. Almost all biodiesel produced in Argentina is made from soybean oil. In February 2019, the European Commission and Argentina agreed to a duty-free quota based on 10% of the EU average annual consumption and a minimum import price[256]. The soy oil industry in Argentina is currently running at 50 percent capacity, however in 2019 the EU quota was not expected to be fully filled due to a large EU biodiesel supply and the use of low-priced palm oil[255].

Currently, Argentine biodiesel exports have come to a complete halt due to a decreasing demand in Europe caused by the coronavirus pandemic. Export biodiesel plants in the country are currently inactive, leading to a soybean oil surplus in Argentina this year[257].

There are no specific environmental sustainability criteria for biofuels in Argentina. However, as the country is a major exporter of biodiesel, the criteria and regulations of other markets are closely monitored for export compliance. The EU's Renewable Energy Directive requires minimum GHG emissions savings level of between 50-60%, therefore certificates granted by for example the Round Table on Responsible Soy Association voluntary scheme accompany Argentine exports[255, 258].

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[251] WWF, 2020. Wildlife corridors help elephants move between habitats in Malaysia. https://www.worldwildlife.org/magazine/issues/summer-2020/articles/wildlife-corridors-help-elephants-move-between-habitats-in-malaysia

[252] EleAid, http://www.eleaid.com/country-profiles/elephants-malaysia/. Source; Sukumar, 2006. A Brief Review of the Status, Distribution and Biology of Wild Asian Elephants Elephas maximus- International Zoo Yearbook.

[253] Fleiss et al., 2020. Conservation set-asides improve carbon storage and support associated plant diversity in certified sustainable oil palm plantations. Biological Conservation, 2020; 248

[254] Tomei and Upham, 2009. Argentinean soy-based biodiesel: An Introduction to production and impacts. Energy Policy, 37-10; 3890-3898.

[255] USDA, 2019. Biofuels Report 2019.

[256] Commission Implementing Decision (EU) 2019/245 of 11 February 2019 accepting undertaking offers following the imposition of definitive countervailing duties on imports of biodiesel originating in Argentina. C/2019/877

[257] Reuters, 2020. Argentina biodiesel exports fully halted due to pandemic. https://www.reuters.com/article/us-argentina-biodiesel-exclusive/exclusive-argentina-biodiesel-exports-fully-halted-due-to-pandemic-chamber-head-idUSKBN22H1Z3

[258] Round Table on Responsible Soy Association, RTRS Standard for Responsible Soy Production V3.1, June 2017.

This section describes the environmental impacts on soil, water, air and biodiversity from the production of soy oil for EU biofuel demand.

Water quality

The biggest impact on water quality resulting from soybean cultivation in Argentina comes from pesticide- and fertilizer use. These agrochemicals are used to efficiently manage farms of increasing size and to reduce labour costs. When sprayed on crops, a fraction of the applied pesticides may reach surface- and groundwater through drift, run-off or drainage. These chemicals are a source of nutrient pollution in rivers and lakes. Recent studies revealed the presence of pesticide residues in fish, surface waters, groundwater, sediments, soils and rainwater of the Pampa region in Argentina[259]. Glyphosate has been marketed as "practically non-toxic", however more research is now discovering the potentially toxic and carcinogenic effects on ecosystems and human health[265].

Furthermore, unsustainable water use and contamination can strain the Guarani Aquifer. The Guarani Aquifer System is one of the largest underground natural reservoirs of freshwater worldwide, which is shared by Argentina, Brazil, Paraguay, and Uruguay[260]. The use of water in soybean cultivation, especially in more arid areas, is still an underdeveloped field of research.

Soil quality

Soy is a relatively low-yielding oilseed crop, producing on average around 500 litres of oil per hectare, therefore requiring vast areas of land. The soybean cropping area has increased from nothing in the 1970s to 18 million hectares in 2018. More than half of Argentina is currently under agricultural production[261]. Soybean plantations are mainly concentrated in the central provinces of Santa Fe, Buenos Aires, Entre Rios, and Córdoba. Most of the soy processing industry is located in the same central region, enabling easy access to the Paraná river[254].

Agricultural expansion has been the key driver of deforestation and habitat loss in Argentina. The Gran Chaco, the second largest forested area in Latin America after the Amazon, has declined by 85% between 1969 and 1999 in Argentina[254]. Under the Renewable Energy Directive land use change and deforestation, to produce soybean oil for biofuel, is prevented by voluntary schemes. However, the expansion of soybean crops does contribute indirectly to land use change by pushing the agricultural frontier and forcing other crops and cattle ranching to less suitable land[262]. To protect native forests in Argentine, the Forest Law came into place in 2017. Since the enactment of the law, the amount of forest loss has slowed by half, from 300.000 hectares a year to 150.000. However, 2.6 million hectares have still been deforested, of which 840,000 hectares were supposedly protected[263]. This extension of agriculture into forested areas will affect biodiversity, soil fertility, and leads to carbon losses from both soil and biomass. Research shows that soybean cultivation in areas with fragile soils carry a greater risk of soil erosion and deterioration, where cultivation in arid areas can cause desertification, and cultivation in low lying areas carry an increased risk of flooding[254].

In recent years, high rates of soil erosion have been reduced by the adoption of new technologies such as no-till cropping. No-till cropping is an agricultural technique for growing crops without disturbing the soil through tillage. Conventional tillage increases the amount of soil erosion, especially in sandy and dry soils on sloping terrain[255]. Other possible benefits from no-till farming include an increase in water infiltration in the soil, retention of organic matter, and nutrient cycling. These

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[259] .D'Andrea et al., 2020. Sensitivity analysis of the Pesticide in Water Calculator model for applications in the Pampa region of Argentina. Science of The Total Environment, 698

[260] Sindico et al., 2018. The Guarani Aquifer System: From a Beacon of hope to a questionmark in the governance of transboundary aquifers. Journal of Hydrology: Regional Studies 20, 49-59

[261] FABLE, 2019. Pathways to Sustainable Land-Use and Food Systems. 2019 Report of the FABLE Consortium. International Institute for Applied Systems Analysis (IIASA) and Sustainable Development Solutions Network (SDSN). www.foodandlandusecoalition.org/fableconsortium

[262] Hoff et al., 2019. International Spillovers in SDG Implementation: The Case of Soy from Argentina. SEI Policy Brief. Stockholm Environment Institute. https://www.sei.org/publications/spillovers-sdg-implementation-soy-argentina

[263] Diálogo Chino, 2019. New images show soy-linked deforestation in Argentina. https://dialogochino.net/en/agriculture/24399-new-images-show-soy-linked-deforestation-in-argentina/

methods may increase the biodiversity and SOC in and on the soil. However, lands that have been classified as highly erodible are still in use for soybean production, therefore the amount of soil erosion is still not fully sustainable. Also, soil compaction is a potential impact as most large soybean farms mechanized their cultivation processes[264].

The expansion of agriculture and the use of no-till agriculture go hand-in-hand with the cropping of genetically modified (GM) soy, and an increased use of agrochemicals[254]. The GM soy used in Argentina is glyphosate-tolerant, and therefore only weeds will be affected by the herbicide[255]. However, weeds are becoming more resistant to glyphosate. Controlling these resistant weeds will require changes in management and increased use of additional herbicides[265]. The widespread application of agrochemicals can lead to changes in soil properties. However, there is little information available about the ecosystem impacts of agrochemicals in Argentina.

Air quality

Soy used to be a high-risk crop for air quality due to the prevalence of burning of crop residues as a means of field preparation or as waste management, and possible pesticide drift-off. However, voluntary schemes under the RED mitigate these risks. The RTST standard for responsible soy prohibits the burning of crop residues, waste, or other burning as part of vegetation clearance on any part of the property. Burning is only allowed as a sanitary measure, for the generation of energy, the drying of crops, or when only small-calibre residual vegetation from land clearing remains[258]. The effect and magnitude of these burning practices on air quality is unknown.

Biodiversity

The expansion of soybean cultivation in Argentina can be a potential risk in terms of indirectly driving deforestation of important biodiversity hotspots. Vulnerable species in these biomes are at high risk of extinction, including almost 100 vertebrates on the Red List of the IUCN[264, 262]. In addition to the biodiversity risks associated with land use change, farm management can also play a role. The interconnections between biodiversity and other environmental aspects have been reviewed in the previous sections on water, soil, and air.

Intensive farming does on the one hand prevent the indirect drive of deforestation, by producing a higher yield per unit area of land. However, intensive farming is a driving force behind biodiversity loss on a farm and field-level. Intensification can have an effect onthe whole food chain. Decreasing numbers and diversity of flora and insects can affect the abundance of small mammals and farmland birds, and lower numbers of insects which may reduce yield and quality in crops[266]. Drivers of biodiversity loss are large monocultures of crops, reduced crop rotation, limited seed exchange between farms, drainage of soils, and increased use of pesticides. Agricultural production relies on good ecosystem functioning and biodiversity. Important processes are pollination by insects, biological pest control, maintenance of soil quality by soil organisms, and nutrient cycling by microorganisms. Also weeds play an important role in these processes, supporting a range of organisms. GM soy cropping systems have a very efficient removal of weeds, reducing the diversity of weeds and seeds significantly. However, it is important to develop farming systems that produce high yield with low environmental impact, drawing on techniques from both organic and conventional systems[267]. To prevent potential trade-off effects, such as biodiversity loss due to higher land demand. Organic farming has a large positive effect on biodiversity. In the last year, a steep increase in organic agriculture has been observed in Argentina. At the end of 2018, 3.6 million hectares of

[264] Wordwilfe.org, Sustainable Agriculture – Soy. WWF.
[265] Bøhn and Millstone, 2019. The Introduction of Thousands of Tonnes of Glyphosate in the food Chain—An Evaluation of Glyphosate Tolerant Soybeans. Foods 2019, 8(12), 669
[266] Schütte et al., 2017. Herbicide resistance and biodiversity: agronomic and environmental aspects of genetically modified herbicide-resistant plants. Environ Sci Eur 29, 5.
[267] Tuomisto et al., 2012. Does organic farming reduce environmental impacts? A meta-analysis of European research. Journal of Environmental Management 112.

farmland were organically managed in Argentina[268]. Some soy farms already produce organic oil, however it is not clear what percentage of soy oil for EU biofuels is produced on organically managed Argentinian farms. It should be noted that organic farms do showcase lower yields and greater yield variabilities compared to conventional farms[269]. It is unclear if this is also the case for organically produced soy in Argentina.

[268] IFOAM, 12 February 2020. Over 71.5 Million Hectares Of Farmland Are Organic! https://www.ifoam.bio/global-organic-area-continues-grow
[269] Smith et al., 2019. Organic Farming Provides Reliable Environmental Benefits but Increases Variability in Crop Yields: A Global Meta-Analysis. Frontiers in Sustainable Food Systems 3:82.

Appendix D. Underlying numbers for graphs in Chapter 3

The following table contains the detailed data for the aggregates of 'other Member States' in ktoe in 2018.

Country	Figure 10: Primary production of solid biomass	Figure 16: Primary production of biogas	Figure 18: Gross electricity production from MSW (renewable fraction)
Austria	4,601	234	29
Belgium	1,231	228	83
Bulgaria	1,524	54	0
Croatia	1,496	74	0
Cyprus	23	13	0
Czechia	3,070	604	9
Denmark	1,774	489	74
Estonia	1,648	14	4
Finland	8,852	186	57
France	10,225	877	189
Germany	11,702	7,631	530
Greece	782	113	0
Hungary	2,132	92	14
Ireland	247	50	28
Italy	7,066	1,892	204
Latvia	2,447	87	0
Lithuania	1,249	37	4
Luxembourg	92	22	4
Malta	0	2	0
Netherlands	1,338	326	187
Poland	6,147	288	7
Portugal	2,662	82	28
Romania	3,443	21	0
Slovakia	908	149	1
Slovenia	549	24	0
Spain	5,441	265	65
Sweden	9,231	176	142
United Kingdom	4,473	2,809	313
EU-28	94,353	16,839	1,973

Appendix E. Underlying numbers for graphs in Chapter 4

The following table contains the detailed data for the aggregates for 'other Member States' and biodiesel and bioethanol combined in ktoe in 2018.

Country	Figure 19: Biodiesel consumption	Figure 20: Bioethanol consumption	Total consumption of biofuels	Figure 21: Biodiesel production	Figure 22: Bioethanol production	Total consumption of biofuels
Austria	441	58	499	206	127	333
Belgium	370	113	483	227	197	424
Bulgaria	135	29	164	114	11	125
Croatia	27	0	27	0	0	0
Cyprus	9	0	9	0	0	0
Czechia	247	61	309	172	48	220
Denmark	173	44	217	0	0	0
Estonia	12	5	17	0	0	0
Finland	281	89	370	281	0	281
France	2,827	585	3,412	2,435	672	3,107
Germany	2,062	753	2,815	2,960	400	3,360
Greece	167	0	167	151	0	151
Hungary	142	52	195	144	302	447
Ireland	121	25	146	27	0	27
Italy	1,220	33	1,252	664	14	678
Latvia	31	8	40	83	5	88
Lithuania	70	8	78	136	11	147
Luxembourg	113	10	123	0	0	0
Malta	10	0	10	0	0	0
Netherlands	378	177	556	1,625	0	1,625
Poland	740	173	912	784	120	904
Portugal	267	6	273	321	0	321
Romania	207	90	297	165	23	188
Slovakia	132	18	150	105	62	166
Slovenia	67	7	74	0	0	0
Spain	1,567	155	1,722	1,561	266	1,828
Sweden	1,477	120	1,597	259	105	364
United Kingdom	900	387	1,287	423	263	685
EU-28	14,194	3,006	17,200	12,845	2,628	15,472

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