Technical assistance in realisation of the 2018 report on biofuels sustainability

Final report

Technical assistance in realisation of the 2018 report on biofuels sustainability

Biofuels, biomass & biogas

used for renewable energy generation

– Final report –

By: Ecofys – A Navigant Company, and Stockholm Environment Institute

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Executive summary

Scope

The Renewable Energy Directive requires the Commission to report on the progress in 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 2017 with a focus on the most recent years. Specifically, the production, consumption and trade of bioenergy are assessed, and the various sustainability impacts of EU consumption of biofuels are quantified. The analysis is based on Member State Renewable Energy Progress Reports submitted in 2017[1], Eurostat SHARES and other Eurostat statistics, other reports and studies, and additional original research.

Overview of bioenergy in the EU, and its main applications

In 2016, bioenergy represented the largest source of renewable energy in the EU, with a gross consumption 140 Mtoe or 65% as shown in Figure S 1. The most important use of bioenergy is in the heating and cooling sector (82.6 Mtoe final energy), followed by electricity generation (15.6 Mtoe final energy) and by transport (14 Mtoe fuels delivered).[2]The majority of liquid bioenergy comes from the use of biodiesels (75%).

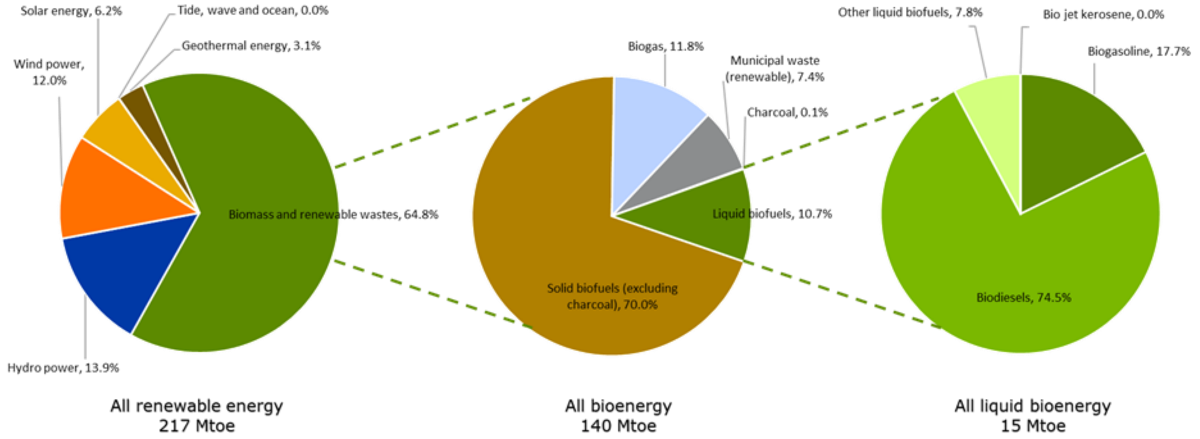

Figure S 1. Gross inland consumption of different types of renewable energy in EU28 in 2016, with details for bioenergy and liquid biofuels in particular. [Eurostat nrg_107a].

In Figure S 2, this consumption per sector is compared 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

[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 (112 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.

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, and sufficient biofuel volumes can be bought on the market.

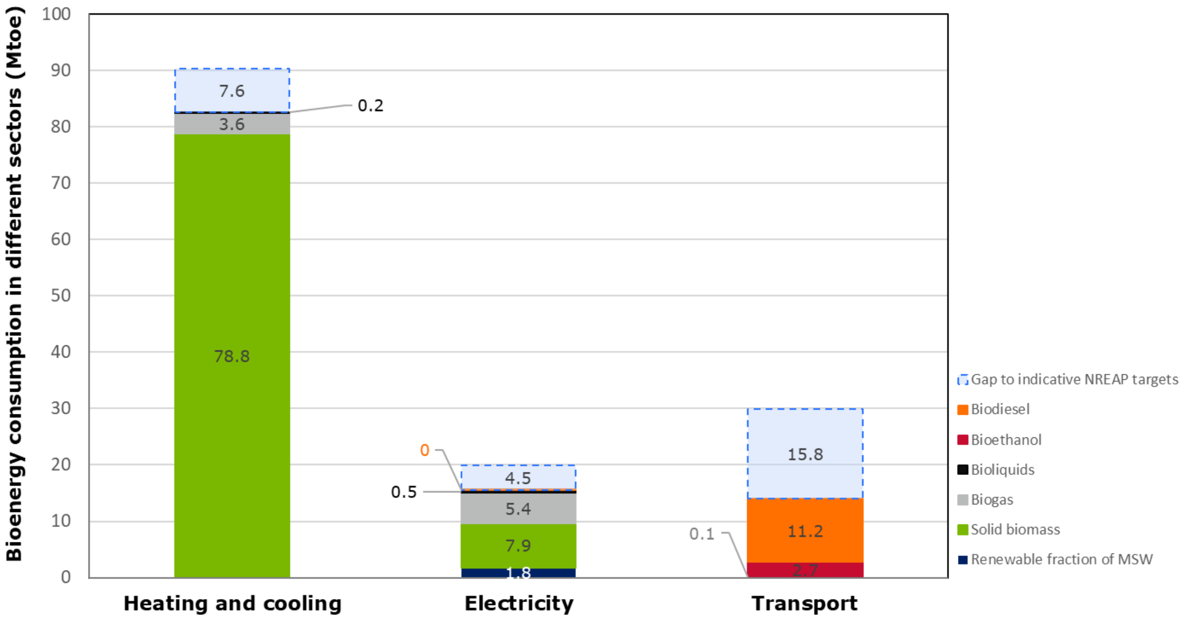

Figure S 2. Bioenergy consumed in the form of heating and cooling, in the form of electricity and as fuel in the transport sector in the EU28 in 2016 compared to 2020 indicative targets specified in NREAPs.[3]

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 energy carrier.

Main bioenergy carriers

Solid biomass is thus the major bioenergy carrier used in the EU for bioenergy production (98 Mtoe gross consumption, delivering 86.7 Mtoe in final energy carriers). The main feedstock for solid biomass is forest biomass

[3] Sources: Bioenergy in electricity generation based on Eurostat nrg_105a, bioenergy in transport based on Eurostat SHARES and nrg_107a,[3] bioenergy in heating and cooling based on 2017 Member State reports,[3] and indicative NREAP targets based on analysis by ECN[3].

(92%, including fuelwood,[4] wood residues and by-products, wood pellets and black liquor[5]). 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, that 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 (92%) of solid biomass consumed in Europe's heat and power generation is sourced from within the EU. In 2016, the largest importer was the UK, responsible for almost 70% of EU imports. The most important third countries supplying solid biomass to the EU were the USA (almost 60% of imports), Canada and Russia (each close to 20% of the imports).

Biogas is the second largest bioenergy carrier in the EU (16.6 Mtoe gross consumption, delivering 9.1 Mtoe in final energy). It is mainly used for the generation of renewable electricity and heat, especially in Germany (8.1 Mtoe), the UK (2.6 Mtoe) and Italy (1.9 Mtoe). A small fraction is consumed in transport.

The consumption of **liquid bioenergy carriers** in the EU (15.1 Mtoe gross consumption, delivering 14.6 Mtoe in final energy carriers) represents 11% of all bioenergy, or 1.2% of all renewable energy (in all sectors). Liquid bioenergy mostly consists of biofuels in transport (11.2 Mtoe biodiesel and 2.7 Mtoe bioethanol), but also accounts for a small amount of so-called 'bioliquids', i.e. liquid forms of bioenergy used for power production in conventional thermal power stations (1 Mtoe gross) and for heat and power in CHP stations (0.3 ktoe gross). These bioliquids are thought to mostly come from vegetable oils and pyrolysis oil.

The renewable fraction of municipal solid waste (MSW, 10.3 Mtoe gross consumption) is also a significant source of bioenergy, especially in the electricity sector (1.8 Mtoe final energy). Overall, the EU has experienced an increasing trend in the use of MSW for bioelectricity generation since 2011. In 2016, Germany was by far the largest consumer of MSW for power generation, accounting for 30% of the EU consumption followed by the UK (13%), Italy (11%), France (10%), the Netherlands (9.5%) and Sweden (8%).

Renewables in transport

For the transport sector, the share of renewable energy in 2016 reached 7.1%,[6] consisting of:

- 3,838 ktoe in Annex IX biofuels (double counted → 2.5%).[7]
  10,225 ktoe in other compliant biofuels (single counted → 3.3%).
- 38.8 ktoe in renewable electricity in road transport (five times counted → 0.06%).

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[4] 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).

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

[6] Following accounting method of Renewable Energy Directive.

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

- 1,464 ktoe in renewable electricity in rail transport (two and half-time counted → 1.2%).
- 351 ktoe in renewable electricity in other transport modes (single counted → 0.1%).
- 0.1 ktoe in other renewable energy (single counted; <0.001%).

The largest part of renewable energy in transport is supplied by biofuels. About 40% of EU biofuel consumption is located 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, such as hydrogen, is small.

Biofuels produced from raw materials listed in Annex IX of the Renewable Energy Directive mainly consist of Hydrogenated Vegetable Oil (HVO) biodiesel, with a current EU production capacity of 2.5 Mtonne per year (in the Netherlands, Italy, Finland, Spain and Portugal), and additional imports from third countries. Note however, that not all HVO is produced from Annex IX feedstocks.[8] In the past it was mainly produced from oil crops. In recent years, however, much of the HVO is produced from waste vegetable oil, and some is also produced from tall oil. In addition, a small share of FAME biodiesel was also produced from UCO and animal fat. Besides these two types of biodiesel produced from raw materials listed in Annex IX B, there have been significant developments in the production of cellulosic bioethanol. However, the market development of this fuel has been slow due to various reasons (technical and/or financial) and some planned projects and operational plants have stopped.

After the strong growth in biodiesel consumption in the decade to 2010, consumption in the EU has been stable in the past five years, at between 11 and 12 Mtoe, with only a temporary dip in 2013. France, Germany, Italy, followed by Sweden and Spain are the largest consumers of biodiesel in the EU.

In 2016, the majority of biodiesel volume (~56%) consumed in the EU market came from feedstocks that were produced in the EU, mainly from rapeseed (~38%), UCO (13%), tall oil (2.5%) and a small fraction that remains unknown. UCO biodiesel also originated from the USA, South East Asia and other countries. The UCO market has been dynamic and in 2017, China started playing an important role as source for UCO biodiesel consumed in the EU. In addition, about 20% of the EU biodiesel volume stemmed from Indonesian (13.3%) and Malaysian (6.3%) palm oil which mainly entered the EU as the final product.

EU bioethanol consumption shows a declining trend in the EU since 2011. This is mostly due to the double counting of bioethanol—which reduces the physical volume of bioethanol required to reach the mandate, lower gasoline consumption in the EU (115 million litres in 2011 vs 102 million litres in 2016) and the adjustment of national bioethanol specific blending mandates. The largest consumers of bioethanol are Germany, France and the UK. About 65% of the bioethanol consumed in the EU in 2016 stems from feedstocks that are produced in the EU, mainly wheat (~25%), corn (~22%) and sugar beet (17%) and only a small amount (~1%) from cellulosic ethanol. Non-EU origin feedstocks account for about 35% of the EU bioethanol market, mainly based on corn originating from Ukraine, Russia, Brazil, Canada and the USA.

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[8] See the 'Terminology' section at the start of the report for an explanation on this.

Of the 28 Member States, 27 have implemented the Directive’s sustainability criteria in their national legislation. Only for Croatia, the status of implementation could not be assessed. Of the 28 Member States seven have already implemented the ILUC Directive in national legislation. Another five Member States have stated that they plan implementation of the ILUC Directive. The other 15 Member States have not mentioned the ILUC Directive or its national implementation in their recent Progress Report.

Land used for biofuel production

Based on a statistical analysis the land required for the production of EU consumed biofuels in 2016 is around 4.9 Mha. Of these 4.9 Mha of land, 3.6 Mha (73%) is estimated to be within the EU and the remaining 1.3 Mha (26%) outside the EU. This figure is likely higher than the actual acreage, because conservative data has been used for the conversion efficiencies and yields. The 3.6 Mha of cropland used for the production of agricultural raw materials for biofuels consumed in the EU in 2016 equals 3.1% of the EU total cropland of 115 Mha. Rapeseed is the main crop in the EU used for biofuels production representing about 56% of the total EU biofuel crop land (about 2 Mha). For countries outside the EU, the share of their cropland that could be related to EU consumed biofuels is minimal. The main third countries providing feedstock for EU biofuel consumption (Ukraine, Brazil, Indonesia and Malaysia) are estimated to dedicate less than 0.5% of their total cropland for production of the EU biofuel feedstocks.

In contrast to these estimates, the Member State Progress Reports indicate a land use of about 20 Mha used for production of crops for biofuels, about 43 Mha for short rotation trees and about 40 Mha for other energy crops. The difference is explained by the fact 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, (b) the fact that responses sometimes included all land used for these categories of crops, not the share specifically dedicated to bioenergy purposes and (c) that not in all cases there is a direct link to the extent the reported feedstocks are actually used for bioenergy purposes within the MS. Therefore, the combined numbers as reported by the Member States are likely too high.

Environmental and socio-economic impacts of biofuels

The Member State Progress Reports indicate a total greenhouse gas emission savings of 33 Mtonne CO_{2eq} in 2016, a marginal reduction (-1.7%) in savings compared to 2015. Independent analysis suggests a slightly smaller total greenhouse gas emission savings of 28.4 $MtCO_2eq$ (60% savings) based on the consumption of 16.5 Mt of biofuels displacing the same amount of energy of fossil fuels. 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 on 2016. 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 (because ILUC is caused by additional demand and the exact impact changes in time). When the 2016 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 is reduced to 11.8 Mtonne CO_{2eq} (with a range from 7.4 Mtonne to 20.4 Mtonne of CO2 savings). 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 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 done on 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 to 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 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.

EurObserv'ER reports a total of 205,100 direct and indirect jobs in the EU related to the biofuel sector in 2016, which is an increase compared to 2015 (178,200). Most of this employment is in Poland (17%), France (16%), Romania (12%) and Germany (11%). The largest part of direct employment arising from EU biofuel consumption is located outside of the EU, in Indonesia and Malaysia.

Several other bioenergy feedstocks besides food crops, such as woody residues, straw, used cooking oil, animal fats, tall oil and fatty acids, have an existing and possibly competing use in other sectors, like oleochemical, animal feed, animal bedding, paper & pulp production or material use. However, given the total amount of feedstock available and the demand for it from these competing sectors, a considerable amount of feedstock (and especially of the types listed in Annex IX of the Renewable Energy Directive) is still expected to be available for biofuel production without causing competition.

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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)
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

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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 applies 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. 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 2018 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 of the Directive is not limited. 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 2018 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”**.
- 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 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 for the production of 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.
- **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.

1 Introduction

In 2009, the European Union adopted the Renewable Energy Directive (also known as the RES Directive, or RED). This Directive established an overall renewable energy target of at least 20% in final energy consumption for the EU and a 10% target for each Member State of renewable energy in transport for 2020. It also defined legally binding national renewable energy targets and required Member States to transpose the Directive into national legislation by 5th December 2010. Finally, it required Member States to implement policies and measures to reach these targets.

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 about 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 on the basis of 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 2018 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 2018 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 2017, SHARES and other Eurostat statistics, other reports and studies, and additional research.

The Renewable Energy Directive has been amended by the ILUC Directive in 2015 in response to concerns about Indirect Land Use Change (ILUC). 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 new Renewable Energy Directive (RED II) was published, covering the period 2021-2030. In the transport sector, this revised Directive, for instance, promotes the deployment of advanced biofuels (defined on basis of feedstock listed in Annex IX A of that Directive). This recast of the Renewable Energy Directive is not directly relevant for the 2015-2016 reporting period but impacts the market as producers, national policy makers and other stakeholders are viewing post 2020 regulatory developments when considering 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 target for renewable energy in transport is evaluated.

In Chapter 3, 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. The 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.

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

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

2 Bioenergy in the EU

Bioenergy represents 65% of the 2016 EU gross renewable energy consumption. The 140 Mtoe of gross bioenergy delivers net 83 Mtoe of heat, 16 Mtoe of electricity, and 14 Mtoe of biofuels for transport. Heat is mainly generated from solid biomass, which mainly concerns forest biomass and forest industry residues and by-products. Half of the bioelectricity is also generated from solid biomass, while biogas delivers about 34%. Bioenergy in transport on the other hand mainly concerns biodiesel and bioethanol.

The generation of heat from biomass is rather 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 relative sense. The gap observed for bioenergy in transport is large, although in principle sufficient volumes of biofuels can be obtained from the (global) market.

2.1 Overview

The majority of gross renewable energy consumption in the EU in 2016 consists of bioenergy (140 Mtoe or 65%), followed by hydropower (14%), wind (12%) and solar (6%), see Figure 1.[10] The fraction of bioenergy in final renewable energy consumption is slightly smaller, because the conversion efficiency to electricity is significantly less than 100%. This will be explained in Section 2.2.

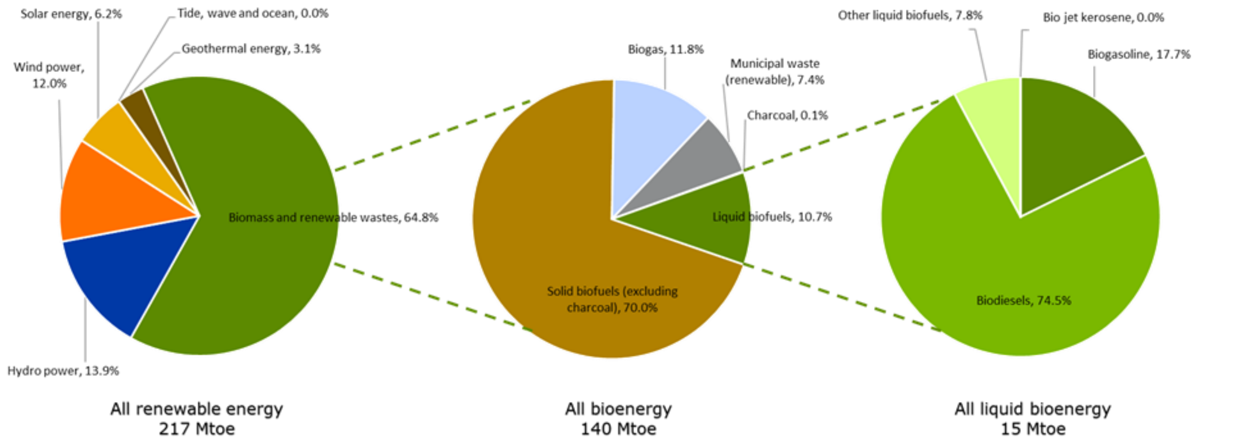

Figure 1. Gross EU consumption of different types of renewable energy in EU28 in 2016, with details for bioenergy and liquid biofuels in particular [Eurostat nrg_107a]. The definitions of materials in this dataset slightly differ from those in the Renewable Energy Directive.[11] Here, "consumption" is measured at the moment the biomass is consumed, e.g. in the production of heat or power, or as a fuel in transport.

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[10] Data in this section is based on Eurostat nrg_107a, unless specified otherwise.

[11] Eurostat nrg_107a 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

About 59% of the EU gross bioenergy consumption served to generate heat, followed by 11% to generate power, while 10% was consumed in the form of biofuels for transport (see Figure 2).[12] Germany was the largest consumer of bioenergy (26.2 Mtoe) followed by France (16.5 Mtoe), Italy (13.2 Mtoe), Sweden (11.6 Mtoe) and the UK (10.7 Mtoe).[13]

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 more detail on the forms of bioenergy contributing to each of the three end-use sectors of heat, power and transport at an EU level. It compares the 2016 bioenergy generation to the sum of 2020 indicative targets set out in all Member States NREAPs. The 140 Mtoe of gross bioenergy delivers *net* 83 Mtoe of heat, 16 Mtoe of electricity and 14 Mtoe energy in transport. The total of this *net* energy is 112 Mtoe. Note that the difference resides mainly in 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, the gap is large in both relative and absolute terms, however, the large gap does not per se imply 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. However, policy frameworks and the market currently limit the deployment of biofuels. This is discussed in more detail in Section 4.1.

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 liquid 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.

[12] The remaining 20% is due to losses along the supply chain and due to transformation efficiencies.

[13] Eurostat nrg_107a.

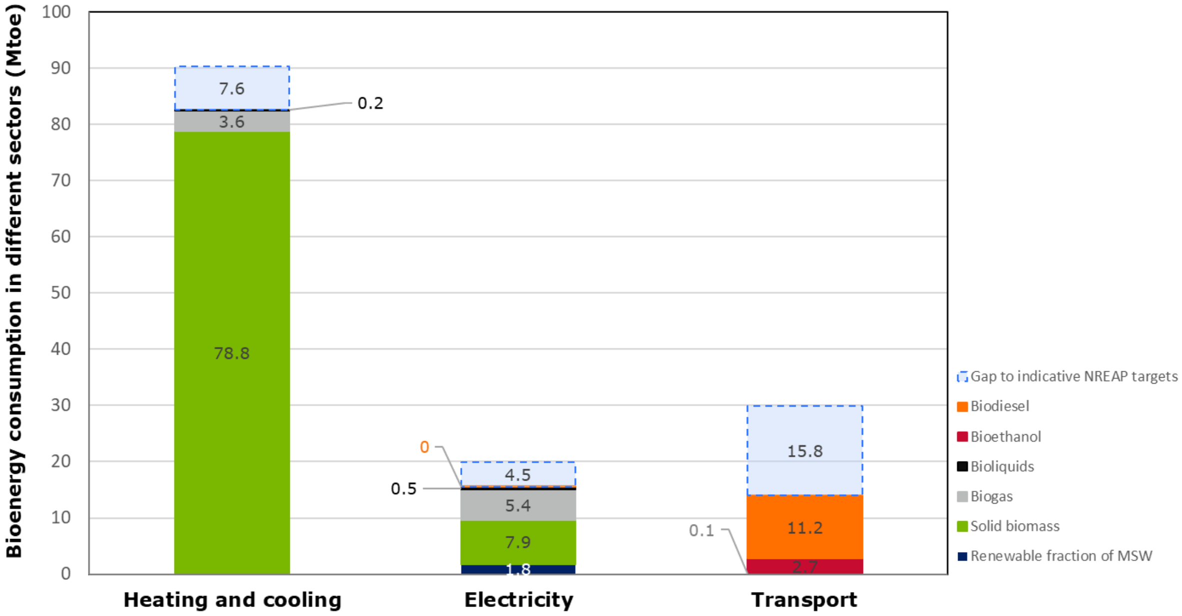

Figure 2. Bioenergy consumed in the forms of heating and cooling, in the form of electricity and as fuel in the transport sector in the EU28 in 2016 compared to sum of the 2020 targets as specified by MS in their NREAPs. Heating and cooling are reported as final consumption, i.e. the amount of heat and 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 based on Eurostat nrg_105a, bioenergy in transport based on Eurostat SHARES and nrg_107a,[14] bioenergy in heating and cooling based on 2017 Member State reports,[15] and indicative NREAP targets based on analysis by ECN[16]].

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. The development of biobased power generation has been on track, while the development of biofuels has been continuously behind schedule. Nevertheless, the total contribution of bioenergy is in line with the sum of the sectoral trajectories.

[14] Note that Eurostat nrg_107a 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. Remarkably, the total of compliant biofuels according to Eurostat SHARES (14,047.3 ktoe) is somewhat higher than the total of bioenergy in transport according to the nrg_107a dataset (13,840.3 ktoe). In this chart the total of compliant biofuels reported in SHARES has been combined with the technical fractions reported in nrg_107a.

[15] Eurostat nrg_106a 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 14.1 Mtoe in 2016. This is much lower than what is reported by the Member States in their renewable energy progress reports (82.7 Mtoe in 2016). 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 75.2 Mtoe and the amount of (additionally) "derived heat" is 14.3 Mtoe (and heat pumps amount to 9.8 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 89.5 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. At the moment of writing, the Member State Progress report for Croatia was not available.

[16] ECN collection of data provided in the Member State National Renewable Energy Action Plans (NREAPs) available via www.ecn.nl/nreap (update 2011).

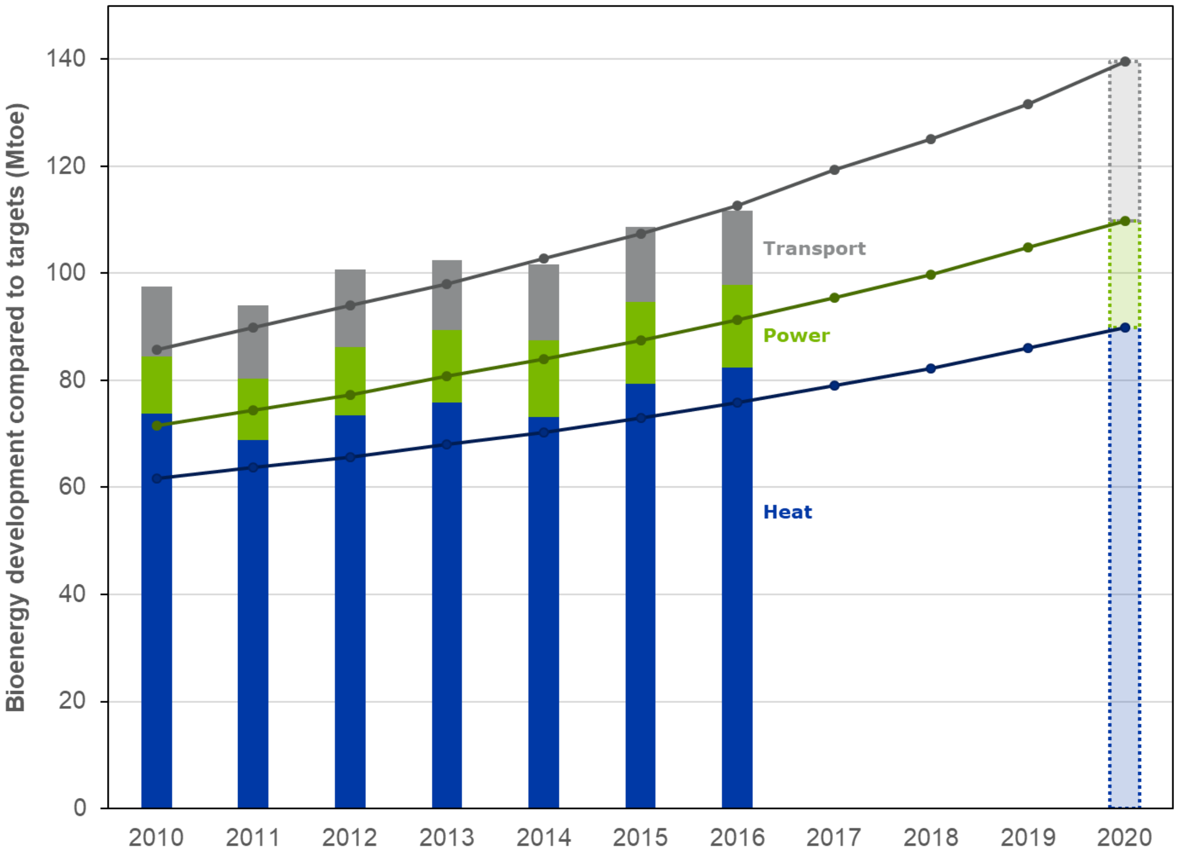

Figure 3. Development of bioenergy consumption in the three sectors over time, for the EU as a whole (bars for the years 2010-2016) and compared to the sum of indicative NREAP trajectories (lines) and 2020 NREAP targets (bar). Note that bioenergy in heating and cooling and transport are reported as "final consumption", in electricity is reported as "gross electricity generation" [Historic achievements based on Member State reports, 2020 indicative targets and trajectories based on NREAPs].

Bioenergy in Heating and Cooling

Bioenergy for heating and cooling in practice concerns heating only.[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 (3.6%), and a smaller contribution from bioliquids (0.1%). Figure 4 shows details per Member State. Germany (14% of EU total) and France (13%) consume the most heating from bioenergy, followed by Sweden (10%), Italy and Finland (both 9%). In most Member States, the deployment of bioenergy in heating in 2016 is already close to their 2020 indicative NREAP sectoral targets. France, however, still faces a large gap between the 2016 achievement and their indicative NREAP sectoral target.

[17] The generation of cooling based on bioenergy was not observed. Cooling on basis of renewable electricity can of course involve bioenergy.

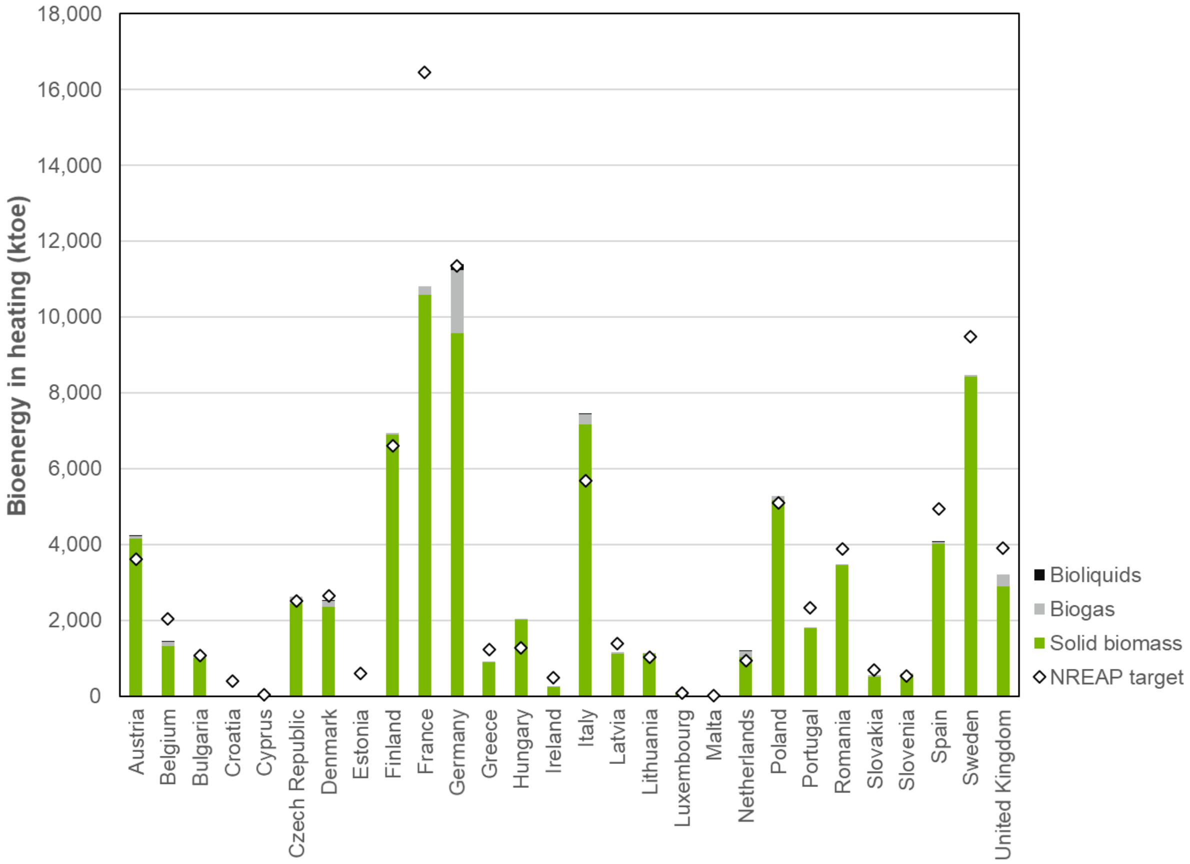

Figure 4. Consumption of bioenergy in the form of heating in 2016 [data from Member State Progress Reports, report for Croatia was not available] compared to 2020 indicative NREAP sectoral targets for bioenergy in heating [ECN[16]].

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. The majority (92%) of solid biomass consumed in EU heat *and power* generation, was sourced from within the EU. It is not possible to derive separate insights into the sourcing for both applications (heat and power). The largest biomass importer was the UK, responsible for almost 70% of EU imports. The most important third countries supplying solid biomass to the EU were the USA (close to 60% of imports), Canada and Russia (each close to 20% of imports). A more detailed analysis of the EU production and consumption of solid biomass, its 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 mainly concerns farm based anaerobic digestion. Crops such as corn, sugar beet and cereals are used as co-digestate at farm level. It is also possible to produce biogas via gasification of solid biomass, but this was not done at a commercial scale in 2016. There is insufficient data to understand the origin of the feedstock for digestion. However, it does not make sense to transport the feedstock for digestion over large distances and, therefore, it can be assumed that all the feedstock was sourced from the EU.[18] All the biogas that was 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 Germany (64%) and Italy (17%). The exact nature of these bioliquids is unknown. Likely they concern vegetable oils, crop-based biofuels similar to those used in transport, and pyrolysis oil.

Bioenergy in Power

At EU level, the contribution of bioenergy to renewable electricity has remained around 19% in the past 5 years (see Table 1). In 2016, bioenergy was the third most important form of renewable electricity behind hydropower (36%) and wind energy (32%), and ahead of solar power (12%). The share of bioenergy in the total power production increased between 2011 and 2014. This was primarily caused by an increase in bioelectricity production, coupled with a decrease in overall power production. The trend has slowed between 2015 and 2016. This is as a result of slower growth in bioelectricity production and an increase in the overall power production compared to preceding years.

Bioenergy consumption in power production in the EU mainly concerns solid biomass (7.9 Mtoe in 2016) and biogas (5.4 Mtoe). The renewable fraction of municipal solid waste (MSW) has a smaller role (1.8 Mtoe) and bioliquids are negligible (0.5 Mtoe). The table shows that both in absolute and in relative terms, biogas and solid biomass were the main drivers behind the growth in bioelectricity.

Table 1. Bioenergy consumption in electricity in the EU28 from 2011 until 2016, in ktoe; All calculations follow rules set out in Directive (EU) 2015/1513; data for total renewable and total generated power are based on Eurostat SHARES, 2016; data for solid biofuels, biogas, renewable MSW, biofuels and total bioenergy are based on Eurostat nrg_105a.

	2011	2012	2013	2014	2015	2016
Solid biomass	6,302	6,834	6,933	7,297	7,802	7,863
Biogas	3,295	4,041	4,627	4,976	5,246	5,392
Incineration of renewable faction of MSW[1]	1,555	1,588	1,609	1,685	1,765	1,810
Bioliquids[2]	285	312	368	417	474	455
Total bioelectricity	**11,437**	**12,775**	**13,538**	**14,374**	**15,287**	**15,519**
Total of renewable electricity	61,181	66,413	70,892	74,916	79,763	82,541
Total generated power	**282,065**	**282,375**	**279,620**	**273,019**	**276,809**	**278,858**
Share of renewable energy in power sector (%)	21.7%	23.5%	25.4%	27.4%	28.8%	29.6%
Share of bioenergy in renewables total (%)	**18.7%**	**19.2%**	**19.1%**	**19.2%**	**19.2%**	**18.8%**
Share of bioenergy in power sector total (%)	**4.1%**	**4.5%**	**4.8%**	**5.3%**	**5.5%**	**5.6%**

[1] MSW: Municipal Solid Wastes

[2] Sum of biodiesel and “other bioliquids” (presumably this includes raw vegetable oil and pyrolysis oil).

[18] 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.

Figure 5 shows the deployment of bioelectricity for each Member State in 2015 and 2016. Typically, the share of bioelectricity in total electricity production is higher than average in more northern located countries (Finland, Sweden, Germany, Latvia, Estonia and the UK), whereas several southern located countries barely use biomass in renewable electricity production (Croatia, Malta, Cyprus, Greece). This is likely related to the larger biomass resource base in the respective Member States (forestry industry, agricultural sector). The UK, however, does not have a large solid biomass resource basis and as we will see in Section 3.1, the UK mostly relies on imports.

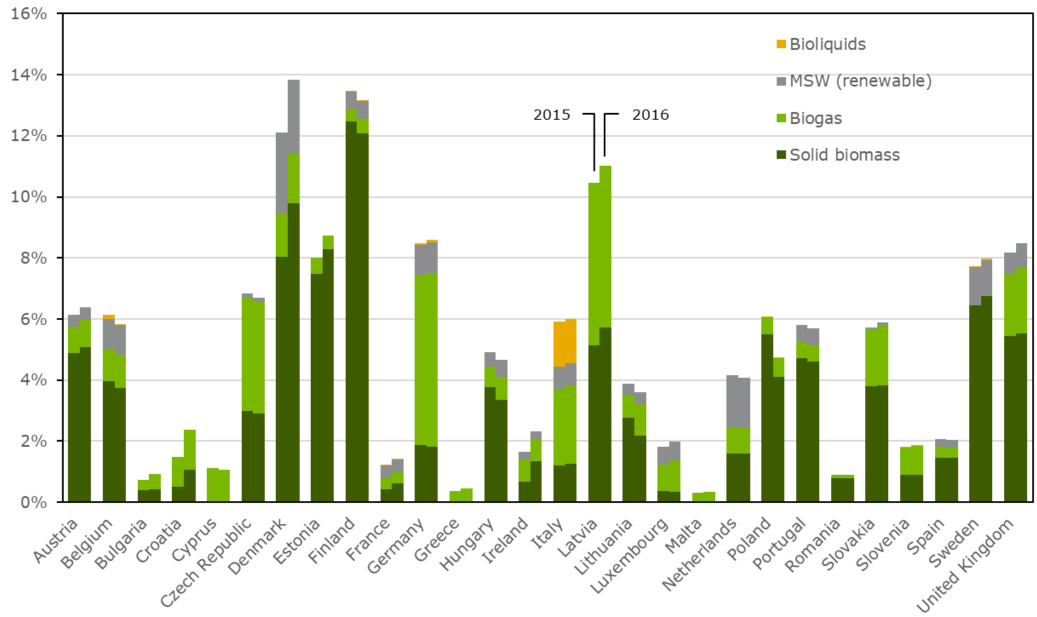

Figure 5. Share of bioelectricity in the total electricity production, in 2015 and 2016 in EU Member States. [Gross electricity generation from various forms of bioenergy are taken from Eurostat nrg_105a and divided by the denominator reported by Eurostat SHARES, 2016].[19]

Figure 6 shows details per Member State on total bioenergy consumption. Germany (28% of EU total) is the largest consumer of bioelectricity, followed by UK (17%) and Italy (11%). These Member States have already achieved their 2020 indicative NREAP targets. Many Member States, however, still face a large gap between the 2016 achievement and their indicative 2020 sectoral NREAP target.

[19] 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_105a. Note that Eurostat nrg_105a and SHARES report the same values for solid biofuels and for the total RES-E denominator, which suggests that nrg_105a 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_105a.

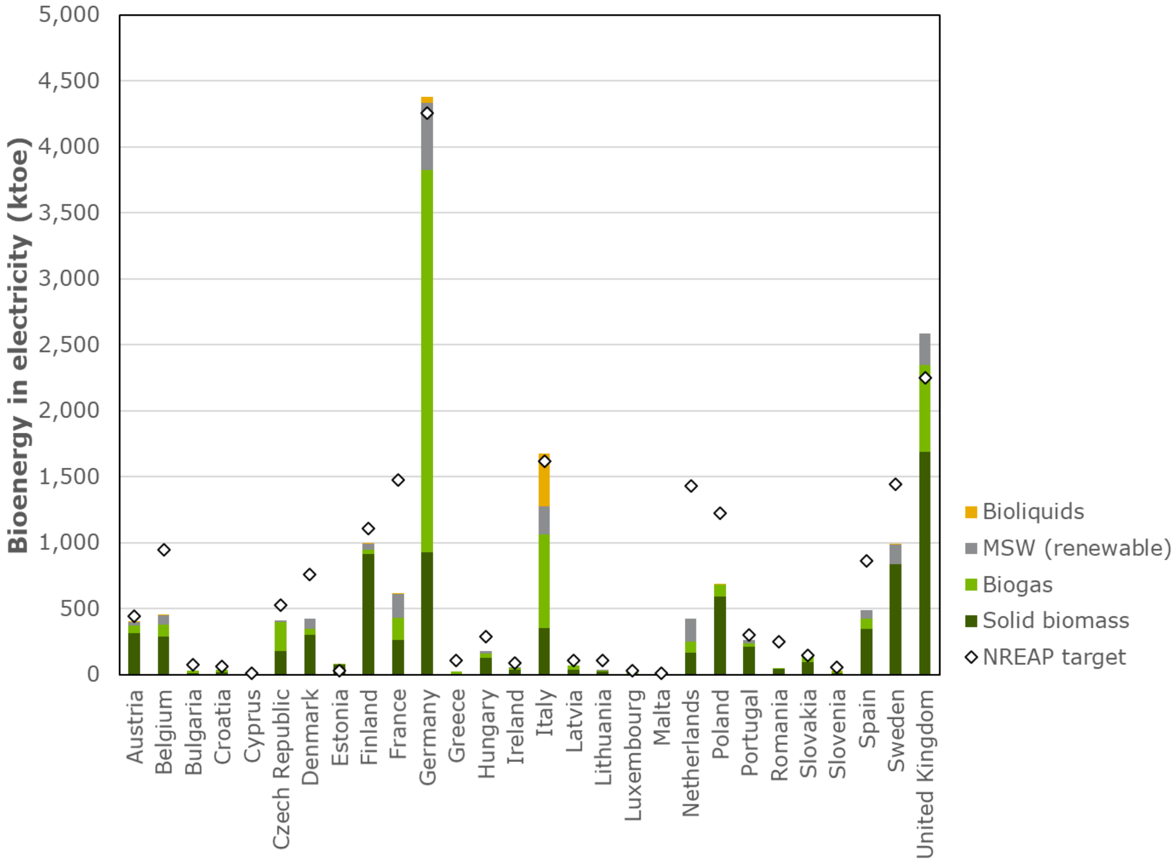

Figure 6. Consumption of bioenergy in the form of electricity in 2016 [data from Member State Progress Reports, report for Croatia was not available] compared to 2020 indicative NREAP targets for bioenergy in power [ECN[16]].

As discussed in the previous section, most of the solid biomass consumed in the EU originates from the EU, with only some 8% being imported. Solid biomass is traded within Europe. The market for solid biomass and details for feedstocks are discussed in Section 3.1.

In the previous section it was also explained that it is likely that the feedstock for biogas originates completely from the EU.

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 2016, Germany was by far the largest consumer of MSW for power generation, accounting for 30% of the EU consumption followed by the UK (13%), Italy (11%), France (10%), the Netherlands (9.5%) and Sweden (8%). The geographical origin of the renewable fraction of renewable MSW is unknown, although it is likely that most originates from the EU.

Bioliquids have only a small role, their deployment is almost limited to Italy and mainly concern vegetable oils, including some imported palm oil.

Bioenergy in Transport

Bioenergy in transport is mainly discussed in Section 2.3, where the progress towards the 2020 10% target for all Member States for renewable energy in transport is assessed, taking 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, which is specifically developed for the renewable energy reporting in the frame of the Directive. In the current section, the absolute amounts of bioenergy are discussed, based on a different Eurostat dataset (nrg_107a), which does not distinguish between the different sustainability categories, but does give more insight into the material forms of bioenergy.[20] Unfortunately, it is complex to fully compare the two datasets as is indicated at the end of the current section.

Table 2 below shows the final bioenergy consumption in the EU transport sector in 2016. Over 99% of this bioenergy was consumed in road transport. There is a small use of biodiesel in rail transport (17 ktoe in Germany, 7 in the Czech Republic) and a smaller use of biogasoline[21] and biodiesel in domestic navigation. The use of bioenergy in aviation (domestic and international) is reported to be zero, although multiple airlines regularly claim to fly on bio jet fuels.[22,23]

The majority (99%) of the bioenergy concerns bioliquids, which mainly is biogasoline and biodiesel. A small amount of biogas is consumed in road transport, especially in Sweden (99 ktoe) and Germany (32 ktoe).

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[20] Eurostat nrg_107a 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 SHARED Eurostat dataset it is clear that renewable electricity plays some role. However, this is not recognised in set nrg_107a.

[21] Eurostat nrg_107a 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.

[22] IATA estimates that the total global consumption of bio jet fuels in 2016 is 13 thousand m3, which equals about 10 ktoe [personal communication with Hamelinck]. Traders estimate that the EU jet fuel consumption in the EU in 2016 was below 500 tonne [personal communication with Hamelinck].

[23] Eurostat explains that currently none of the EU countries transmit data on bio-jet kerosene to Eurostat, and if the actual amount is less than 500 tonnes per year, it can be rounded to zero [Personal communication with Eurostat].

Table 2. Final bioenergy consumption in EU transport in 2016 in ktoe [Eurostat nrg_107a].[1)] 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 "-".

	Solid biofuels	Biogas	*Biogasoline*	*Biodiesel*	*Other liquid biofuels*	*Bio jet kerosene*	Total Liquid biofuels	Total
Road	-	131	*2,619*	*11,041*	*4.5*	-	13,664	**13,796**
Rail	0.1	0.0		*32.9*	*0.0*	-	32.9	**33.1**
International aviation	-	-	*0.0*	*0.0*	*0.0*	*0.0*	0.0	**0**
Domestic aviation	-	-	*0.0*	*0.0*	*0.0*	*0.0*	0.0	**0**
Domestic navigation	-	0.0	*1.4*	*3.5*	*0.0*	-	5.0	**5.0**
Non-specified transport	-	0.5	*0.0*	*6.2*	*0.0*	*0.0*	6.2	**6.7**
Total	**0.1**	**132**	***2,620***	***11,083***	***4.5***	***0.0***	**13,708**	**13,840**

1) Eurostat categories "charcoal" and "municipal solid waste" are excluded from the table, as they are not consumed in transport according to Eurostat nrg_107a. Eurostat category "consumption in pipeline transport" consumes no renewable energy and has been excluded from the table.

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 both the bioenergy forms as well as the sectors where these are deployed, per Member State. In absolute volumes, Germany and France are the largest consumers of bioenergy in transport, followed by Sweden, Spain, Italy and the UK.

Most Member States have not yet achieved the 2020 indicative targets they have 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 the level of those targets within the next few years. Sweden and especially Germany have surpassed the level of their original NREAP targets by far.

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, the policies are rather driven by the 10% overall target for renewable energy in transport as is analysed in the next section.

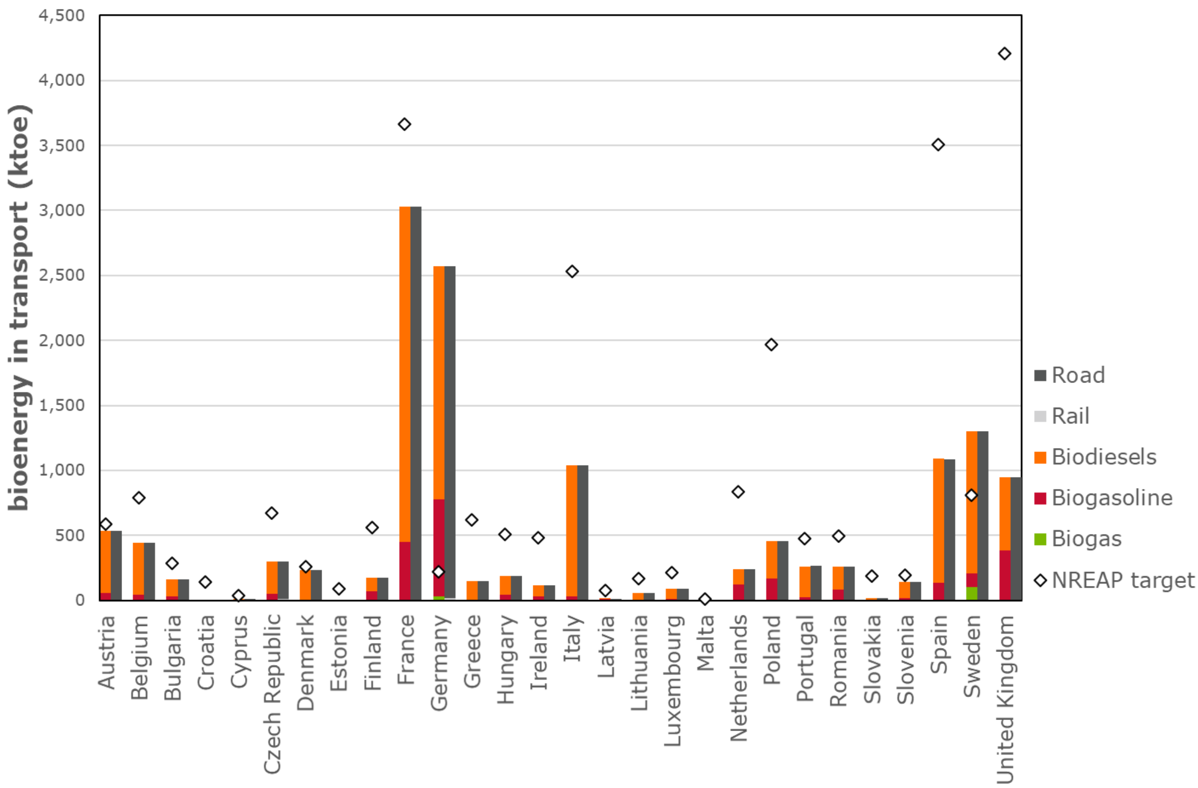

Figure 7. Consumption of bioenergy in transport in 2016 [Eurostat nrg_107a] compared to NREAP targets [ECN[16]].

2.3 Progress towards the 2020 targets for renewable energy in transport

Renewable energy use in transport, known as RES-T, has continuously increased since 2004 (apart from an administrative dip in 2011 and 2012[31]). As can be seen in Table 3, today biofuels represent most of the renewable energy in transport. By and large, these biofuels are biodiesel and bioethanol directly replacing fossil diesel and gasoline respectively. About 40% of the EU biofuel consumption takes place in France and Germany.

In 2016 the total share of renewable energy in EU transport reached 7.2%,[24] consisting of biofuels,[25] renewable electricity and other renewable energy, see Table 3.

[24] 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.

[25] Note that biofuels for transport, as defined in the Renewable Energy Directive, also includes biogas.

Table 3. Share of renewable energy in transport, in real deployment and administrative contribution (after applying multiplication factors) towards the 2020 sum of 10% MS target of the Renewable Energy Directive [Eurostat SHARES].

	Real deployment (ktoe)	Multiplication factor	Administrative contribution (ktoe)	Resulting RES-T share
Annex IX biofuels	3,840	2 x	7,680	2.5%
Other compliant biofuels[1)]	10,241	1 x	10,241	3.3%
Non-compliant biofuels	176			
Renewable electricity in road transport	32.8	5 x	164	0.05%
Renewable electricity in rail transport	1,499	2.5 x	3,747	1.2%
Renewable electricity in other transport modes	321	1 x	321	0.1%
Other renewable energy	0.2	1 x	0.2	<0.0001%
Total RES-T numerator			**22,154**	**7.2%**
Total RES-T denominator			309,381	

1) "Other compliant biofuels" includes biofuels that fulfil the sustainability criteria but that are not categorized as "Annex IX" by the ILUC directive.

The majority of biofuels used were liquid biofuels (see also Figure 2), mainly biodiesel[26] (80%) and bioethanol (19%) with gaseous biofuels representing only a minor share (1%).[27]

The share of renewable energy in transport is estimated to be 7.6% in 2017.[27] To meet the 2020 sum of MS targets of 10% renewable energy in transport, the share should increase at a faster rate in the coming years. On the basis of an analysis of existing and anticipated policy measures, it is expected that some countries will exceed their 2020 target, but the EU as a whole will not reach an overall share of 10%.[28]

In the 2009 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 that increases the market value of double counting biofuels,[29] and this has caused a strong increase in this type of fuels, in particular for biodiesel based on used cooking oil, tall oil, and waste based biogas (see Section 4.3). Today, these Annex IX biofuels account for almost half of the biofuel share (after double counting). The "other compliant biofuels" concern biofuels that fulfil the sustainability criteria, but

[26] Note that hydrotreated vegetable oil (HVO) and hydrotreated crude tall oil (HCTO) are included in the biodiesel category.
[27] Provisional estimate in Eurostat SHARES dataset of 31 January 2019.
[28] See Ecofys, 2018, Technical assistance in realisation of the 2018 report on renewable energy - Progress on Renewable Energy in the EU. On basis of existing and forthcoming legislation, it is forecasted that by 2018 seven countries (Sweden, followed by Latvia, Bulgaria, France, Lithuania, Denmark and Slovakia) will be able to meet (or surpass) their planned deployment target for renewables in the transport sector (mostly biofuels), for some of those however only under specific circumstances. At EU-level a deficit in the magnitude of 34% to 40% may consequently arise. In contrast to other sectors and technologies, there is already sufficient production capacity (and additionally, biofuels can be imported from abroad). Depending on support measures that can be introduced in the next few years, it is possible that the target will be met or exceeded by 2020.
[29] 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.

that are not categorised as "Annex IX". It concerns biofuels from a range of feedstocks according to Article 3(4)d and e of the ILUC directive.[30]

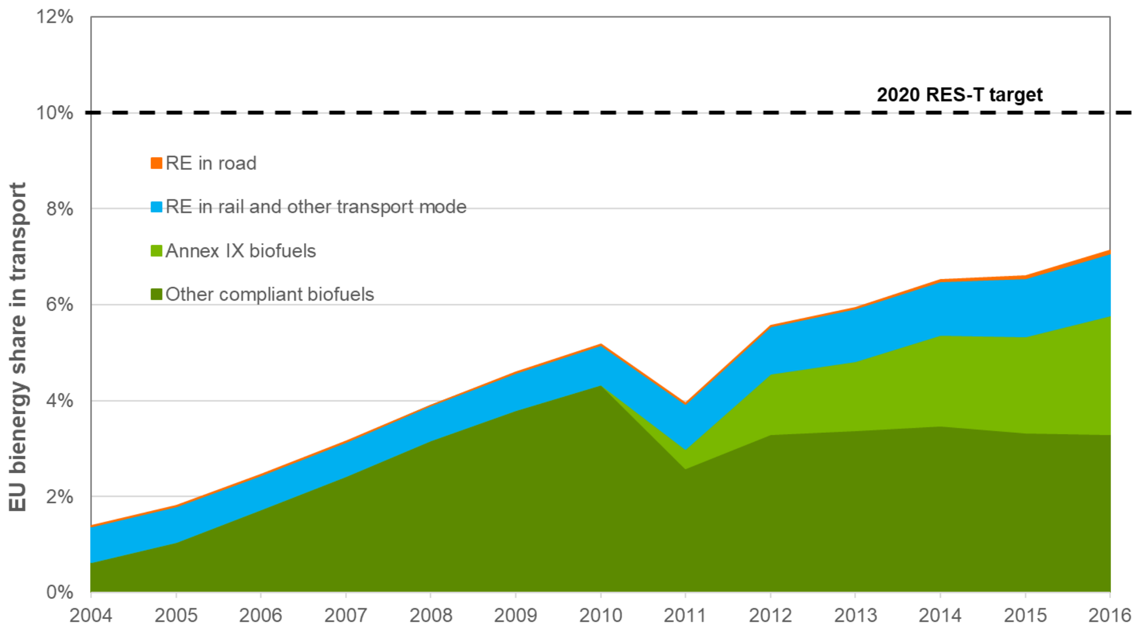

Figure 8. Historical overview of renewable energy in EU transport, after application of multipliers for renewable electricity and Annex IX biofuels in line with the ILUC Directive [Eurostat SHARES].[31]

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 the figure, the contribution is considerable, but note that electricity in rail was counted 2.5 times. Electricity in road transport is negligible, but slowly increasing (further discussed below).

After years of strong growth between 2005 and 2010 (0.7 percentage point per year on average), since 2012 the share of renewable energy grew at a slower pace (0.4 percentage point per year on average). 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,

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[30] 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*" […].

[31] 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 Czech Republic, 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.

which de facto led to the use of biofuels with higher greenhouse gas savings, while requiring less volumes to achieve these savings.[32]

In 2015, the ILUC Directive (Directive 2015/2013) came into force, amending Directive 2009/29/EC, introducing a 7% cap on the share of food crop-based biofuels and a non-binding national target for "Annex IX A"[33] biofuels of 0.5%. In some Member States this 7% limit was already (almost) reached and these countries did not further raise their demand for these crop-based biofuels. Concurrently, the previously mentioned strong increase of double counting Annex IX B biofuels has de facto led to a decrease of the physical deployment of biofuels (before double counting) since the double counting allows companies to meet their blending targets with less volumes of biofuels.

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. There has been a 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[34] 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 relabel fresh oil to used cooking oil without cooking it. 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, used cooking oil 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 used cooking oil, the recast of the Renewable Energy Directive limits the contribution of fuels from Annex IX B feedstocks to a maximum of 1.7%.[35] The global potential for waste oils is sufficient to provide feedstock for EU biofuels up to this limit. The greatest potential lies in countries such as Romania, Malta and Cyprus, that currently have low collection rates from restaurants (less than 50% of UCO potentials from restaurants is currently being collected in these countries). Also, the collection from households could deliver a very large potential, but this is difficult to implement on a commercial basis due to lack of public awareness and collection infrastructure.[36] Currently, the potential of UCO from European households is

[32] 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 CO2eq/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].

[33] 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.

[34] 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

[35] Member States can individually modify this limit, subject to the approval of the Commission.

[36] Global Waste Grease Supply, LMC International, 2017.

estimated to be around 800 ktonne to 900 ktonne per year and only about 6% (less than 50 ktonne) of this is currently being collected.[37]

The feedstocks for biofuels and their geographical origin are discussed in more detail in Sections 4.3 and 4.4.

Figure 9 gives more detail on the application of renewable energy in transport in the Member States.

- **In 2015, Sweden, Finland and Austria already achieved the level of their 2020 RES-T target** by achieving shares of 24%, 22% and 12% of renewable energy in transport, respectively. While in Sweden and Finland most of the RES-T was from Annex IX biofuels (double counting biofuels, including the multiplicators), in Austria it stemmed mainly from use of other compliant biofuels (single counting biofuels).
  - **Finland shows a surprisingly strong decrease in biofuels in 2016 compared to 2015**. Since a new law caps the options for transferring surpluses (administratively) to the following years, it has become less attractive to surpass the mandated volumes. It is expected that Finland will again see increasing volumes of biofuels as the Act on promoting the use of biofuels for transport sets an obligation of 20% in 2020. In 2016, the government announced to increase the share of biofuels in road transport fuels to 30% by 2030.[38]
  - Finland is also the country with the largest share of Annex IX biofuels, this concerns mainly HVO biodiesel produced from waste oils and residues.[39]
  - **Sweden achieved more than 30% of RES-T in 2016** due to a significant increase in the use of Annex IX biofuels (double counting biofuels). Of these double counting biofuels, 88% represents HVO biodiesel, 11% represents biogas and the remaining represents small amounts of ethanol, DME and FAME biodiesel from waste.[40] The use of renewable electricity in trains contributes 4.4% (administratively, i.e. after the multiple counting).
- **From 2015 to 2016, 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.
  - Deployment of biofuels decreased in Croatia, caused by reductions in market supporting subsidies.[41]
  - Spain showed a significant increase in RES-T. This was caused by an administrative correction as from 2011 to 2015, Spain only reported non-compliant biofuels because it was not yet able to register the compliance with sustainability requirements for biofuels sold in the Spanish market. In 2016 the non-compliant biofuels disappear from the statistics, and the volume of compliant biofuels reported is somewhat above the earlier volume of non-compliant biofuels.

[37] Analysis of the current development of household UCO collection systems in the EU, Greenea, 2016.

[38] Reuters, 2016 November 24, Finnish government lifts biofuel targets.

[39] 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 it's application as a waste feedstock, which is allowed by the ILUC Directive.

[40] Sweden renewable energy progress report, 2017. Actually, this report does not mention biofuels based on Annex IX type feedstock, but based on Article 21 (2) from the original Renewable Energy Directive, which concerns " biofuels produced from wastes, residues, non-food cellulosic material, and ligno-cellulosic material". This category preceded the later more elaborated list of Annex IX that was introduced by the ILUC Directive.

[41] ETIP Bioenergy, 2016, Biofuel fact sheet – Biofuels in Croatia.

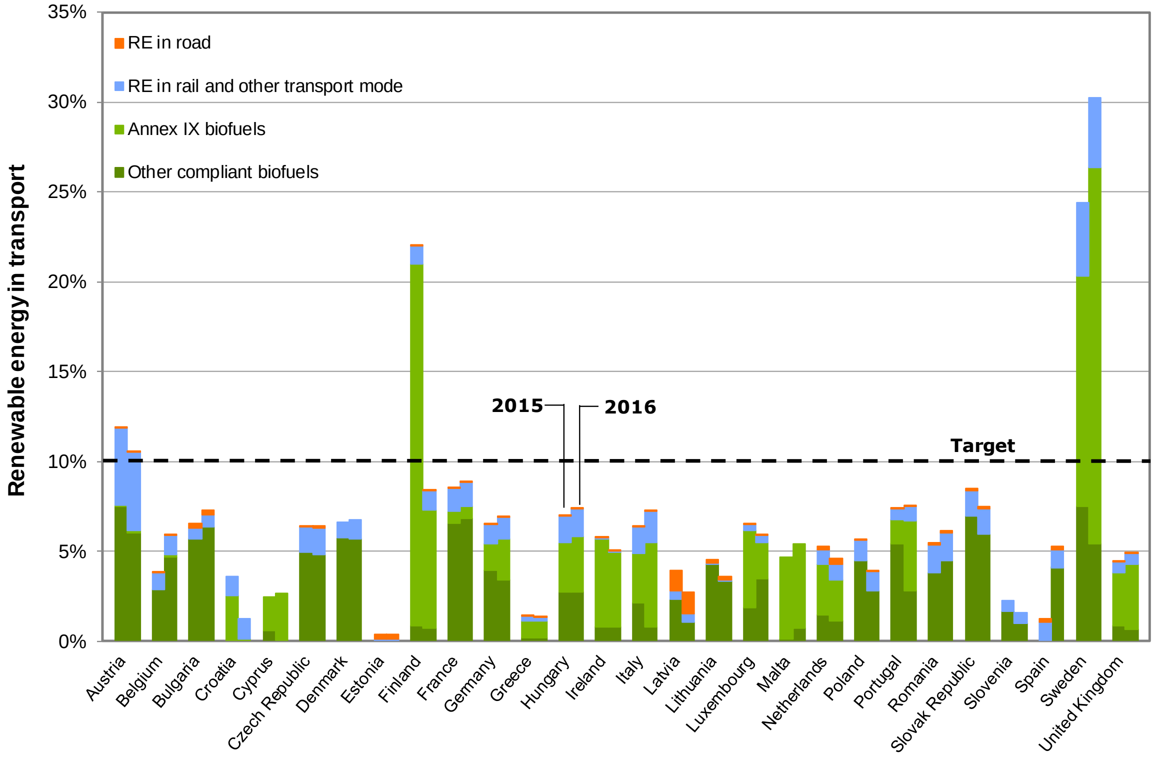

Figure 9. Development of renewable energy in transport between 2015 and 2016 in the EU Member States. Categories and accounting are according to the methodology set out in Directive 2015/1513 [Eurostat SHARES 2016].

The contribution of renewable electricity in transport mainly concerns electricity in rail transport (and other non-road transport), and it is most significant in countries that have high shares of renewable electricity in the grid (see Figure 5). 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[42] in the EU has grown sharply from 59,000 in 2013 to 291,000 in 2017 and 386,000 in 2018.[43] 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 132 ktoe) of the total bioenergy used in transport. In fact, there are only a few Member States including Sweden, Germany, Austria,

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[42] pure electric and plug-in hybrids.

[43] European Alternative Fuels Observatory, eafo: http://www.eafo.eu/

Finland and Denmark using biogas in transport. Sweden and Germany together account for 99% (75% Sweden and 24% Germany) of the total EU biogas consumption in transport.[44] In Sweden, more than 90% of biogas is produced from various waste streams. The main waste substrates for biogas production in Sweden are sewage sludge, food waste, manure and landfill gases which account for 34%, 21%, 19% and 9% of the total biogas produced in Sweden in 2016.[45] In Germany, however, the main substrates for biogas production are agricultural products (51%, mainly maize and grass silage) and manure (41%).[46]

Hydrogen falls in the category of "other renewable energies", which contribute less than 0.0001%.

Table 4 provides a detailed historical overview of biofuels and other renewable energies used in transport in the EU.

Table 4. Renewable energy consumption in all transport in the EU28 from 2011 until 2016, in ktoe [Eurostat SHARES]; All calculations follow rules set out in Directive 2015/1513.

Product/time	2011	2012	2013	2014	2015	2016	2017[1)]
Renewable electricity in road	10.6	11.0	14.7	18.4	24.0	32.8	40.4
Renewable electricity in rail	1,073	1,099	1,203	1,266	1,367	1,499	1,571
Renewable electricity in other modes	217	217	244	257	308	321	327
Compliant biofuels	8,448	11,163	11,418	12,453	13,093	14,081	15,192
- Annex IX	599	1368	1727	1943	3002	3840	4040
- Other compliant biofuels[1)]	7,849	9,795	9,691	10,510	10,092	10,241	11,152
Non-compliant biofuels[3]	5,290	3,385	1,898	1,959	1,132	176	201
Other renewable energies	0.0	0.1	0.4	0.4	0.1	0.2	0.1
Total renewable energy in transport (including multipliers)	12,000	15,551	16,469	17,888	19,816	22,154	23,651
Total fuels used in transport[4)]	**303,317**	**294,409**	**290,868**	**295,052**	**300,371**	**307,381**	**312,792**
RES-T Share (%)	**3.96%**	**5.28%**	**5.66%**	**6.06%**	**6.60%**	**7.21%**	**7.56%**

1) The January 2019 update of Eurostat SHARES contains partial provisional results for 2017.
2) Other compliant biofuels and biofuels included in the first and third paragraphs of article 3(4)d of the Directive 2015/1513
3) "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.
4) Total electricity, diesel, gasoline and biofuels used in the transport; biofuels included with multiplicators.

[44] Eurostat database, nrg_107a

[45] Sweden national biogas strategy 2.0, April 2018

[46] Bioenergy in Germany, facts and figures 2017, published on FNR website

3 Bioenergy carriers and their origin

The use of bioenergy in heating and cooling, in power production and in transport was discussed in detail in Chapter 2. The current chapter provides more detail on the different carriers of bioenergy 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.[47]

Solid biomass is the main form of biomass for energy, as it represents 96% of the bioenergy in heating (which in turn represents 74% of all bioenergy), and 51% of bioenergy in power (14% of all bioenergy). Most of this solid biomass (92%) originates from the EU and mainly consists of forestry and forest industry products and residues (93%), and a smaller share of agricultural and agro-industrial waste. The UK is the largest importer of solid biomass from third countries, mainly from the USA and Canada. The USA, Canada and Russia are together also responsible for 90% of the EU import of solid biomass.

Biogas is the second largest form of bioenergy in the EU representing a 12% share of all primary bioenergy, or 16.6 Mtoe. It produces 3.6 Mtoe of heat and 5.4 Mtoe of power. Germany is by far the largest producer and consumer of biogas. Most of the biogas is produced from crops, agricultural residues such as manure and food-industry residues. Only the UK has a large biogas production from landfills. Most, if not all, the feedstock for biogas consumed in the EU originates from the EU.

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, used cooking oil, animal fat and biodiesel.

The contribution of the renewable fraction of municipal solid waste (MSW) to the total bioenergy consumption was 12% in 2016. This concerns mainly power production. All this MSW originates from the EU.

3.1 Solid biomass

Consumption of solid biomass for energy in the EU

Almost all bioenergy consumed in heating and cooling in the EU in 2016 was based on solid biomass (96% of the total equal to 78.8 Mtoe) as was indicated in Figure 2 in the previous chapter. The major EU consumers of solid biomass for heat production were France (10,575 ktoe), Germany (9,566 ktoe), Sweden (8,418 ktoe), Italy (7,175 ktoe) and Finland (6,897 ktoe). These countries accounted for more than 50% of the total in 2016 (see Figure 4, also in the previous chapter).

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

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 (1,685 ktoe), representing 21% of the EU total, followed by Germany (928 ktoe), Finland (912 ktoe) and Sweden (838 ktoe) (Figure 4).

The total consumption of solid biomass in both heat and power production in the EU in 2016 is estimated to be 86.7 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 98.3 Mtoe, reported by Eurostat, as both shown in Table 6 later in this section. This discrepancy cannot be explained from the available data.

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 & paper industry), energy crops and short rotation trees, and agricultural and food industry wastes and by-products. A few Member States (France, Germany, Sweden, Italy and Finland) report on the nature of the solid biomass used for heat and power generation, see Table 5.[48] Forest biomass from forest and other wooded lands was the main source of solid biomass for heat and power generation, with the exception of Sweden where residues and by-products from the forest-based industry were the major feedstock.

For instance, in Finland, a country with a large forest industry, bioelectricity is mainly sourced from wood: about 33% comes directly from the forest and 31% concerns residues from forest-based industry; the remaining 36% concerns agricultural and food industry residues. Also, in Sweden, by far the majority of bioelectricity comes from wood: 22% directly from the forest, 8% from short rotation trees and 70% from forest-based residues. In Germany, 60% of the solid biomass concerns wood from forests and 31% concerns wood (industry) residues, while crops and agricultural by-products are mainly used for biogas production (Section 3.2).

Table 5. Supply of solid biomass for heat and electricity in major EU consumers of solid biomass in 2016 [data are based on Member States Progress Reports, 2017].

	France		Germany		Sweden		Italy		Finland	
Feedstocks	**Domestic**	**Import**	**Domestic**	**Import**	**Domestic**	**Import**	**Domestic**	**Import**	**Domestic**	**Import**
Wood biomass from forest and other wooded lands for energy generation	10,012	191	5,049	1,016	2,250	4	5,612	398	1,714	0
Wood biomass residues and by-products from wood industry	0	332	2,343	812	6,694	519	600	836	1,593	0
Energy crops and short rotation trees	0	0	0	0	678	173	1,339	3	0	0
Agricultural by-products/processed residues and fishery by-products[1)]	448	0	968	0	14	42	1,053	713	1,849	0
Total	**10,460**	**523**	**8,360**	**1,828**	**9,636**	**738**	**8,604**	**1,950**	**5,156**	**0**

1) In Germany, these feedstocks were mainly used for biogas generation.

[48] Data are from Member State's reports. Note that Member States did not split the solid biomass consumption between the electricity and heat sectors.

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 and Germany imported 18% of their total consumption (fraction of import in sum of import and domestic supply), France and Sweden imported less than 7% of their consumption and Finland met its consumption solely through domestic supply. International trade is discussed later in this section.

Production of solid biomass for energy in the EU

Figure 10 shows how the solid biomass production for energy purposes in the EU gradually increases between 2011 and 2016. The increasing production is mainly driven by the increasing demand for both renewable heat and renewable electricity in the EU as was assessed 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 producer of solid biomass for energy, followed by France, Sweden and Finland.

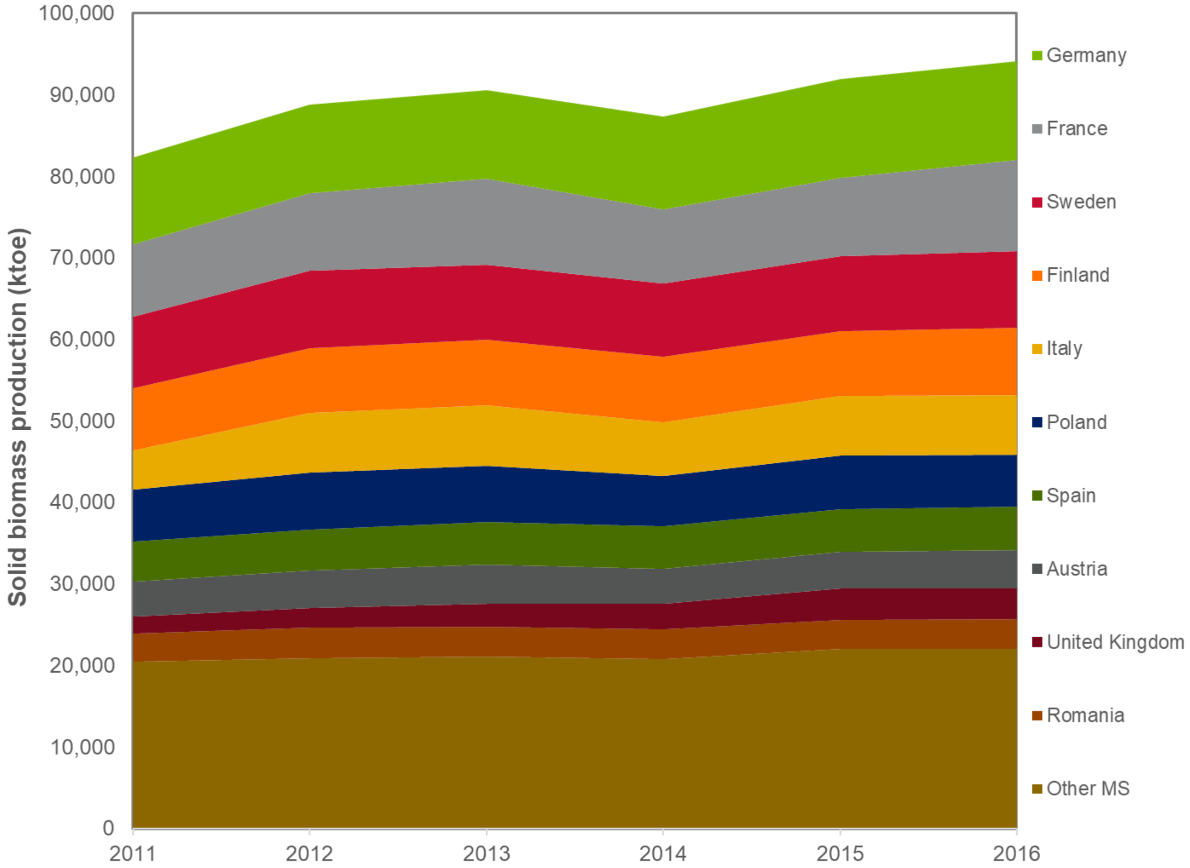

Figure 10. Solid biomass primary production in the EU28 between 2011 and 2016; Data are shown for the 10 Member States with the largest production volume in 2016; The other Member States are aggregated [Eurostat nrg_107a data on "solid biofuels"[49]].

Table 6 shows solid biomass production in the EU between 2011 and 2016, differentiated by feedstock types. The major feedstocks for solid biomass have been forms of wood (~79%, including fuelwood[50], wood residue and by-products as well as wood pellets) followed by black liquor (~14%).

[49] Note that Eurostat does not give statistics on "solid biomass", but rather on "solid biofuels". We presume these terms effectively cover the same material scope.

[50] 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

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Table 6. Solid biomass production in the EU, for energy application, and per feedstock category [Eurostat nrg_109a on "solid biofuels"[49]], import to the EU, export from the EU, and consumption in the EU [Eurostat nrg_107a, which does not allow differentiation to underlying feedstocks]. All volumes reported in ktoe.

Product/time	2011	2012	2013	2014	2015	2016
Fuelwood, wood residues & by-products	60,563	67,107	68,079	65,070	68,024	70,349
Wood Pellets	1,907	2,559	3,075	3,124	3,328	3,561
Bagasse	322	316	326	301	235	321
Black liquor 1)	12,057	11,690	12,153	12,151	12,317	12,718
Other vegetal materials and residues	7,245	6,880	6,471	6,166	7,769	7,021
Animal waste	177	172	291	417	162	156
Total EU solid biofuels production	**82,271**	**88,724**	**90,395**	**87,230**	**91,834**	**94,125**
Total import of solid biofuels	**5,101**	**5,306**	**6,438**	**7,665**	**7,594**	**8,026**
Total market (EU production + import)	**87,372**	**94,030**	**96,833**	**94,895**	**99,428**	**102,151**
Total export of solid biofuels	**2,355**	**2,766**	**3,198**	**3,617**	**3,789**	**3,877**
Total consumption of solid biofuels	**84,851**	**91,188**	**93,761**	**91,211**	**95,587**	**98,280**
Statistical difference (market - consumption – export)	166	76	-126	67	52	-6

1) Eurostat categorises black liquor as a solid biofuel, while it is technically a viscous liquid.

The import of solid biomass has slowly increased from 5.8% in 2011 to 7.8% in 2016 as can be seen from Table 6. The origin of imported solid biomass is further discussed later in this section.

In Figure 11, details on the share of feedstocks in the primary production of solid biomass are given per Member State. German solid biomass production amounted to 12,170 ktoe in 2016, 92% of which was from forest biomass[51] (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.[52] Similar to Germany, the majority (82%) of solid biomass in France concerns wood-based products (Figure 11). In Sweden and Finland, a significant amount of solid biomass (42%, Figure 11) is sourced from domestically produced black liquor – a by-product of the Kraft wood pulping process.[53] These two countries are the largest producers of black liquor in the EU and together account for about 60% of the EU production,[54] followed by, Portugal,[55] Austria, Germany and France.

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[51] Note that the term "forest biomass" is used in the RED II, 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.

[52] Pellet market country report France, ADEME: https://pelletsatlas.info/wp-content/uploads/2015/09/France_CR.pdf

[53] Eurostat includes "black liquor" in its definition of "solid biofuels". Technically, black liquor is a liquid, albeit very viscous.

[54] Eurostat database, energy statistics, nrg_109a

[55] http://ec.europa.eu/DocsRoom/documents/10271/attachments/10/translations/en/renditions/pdf

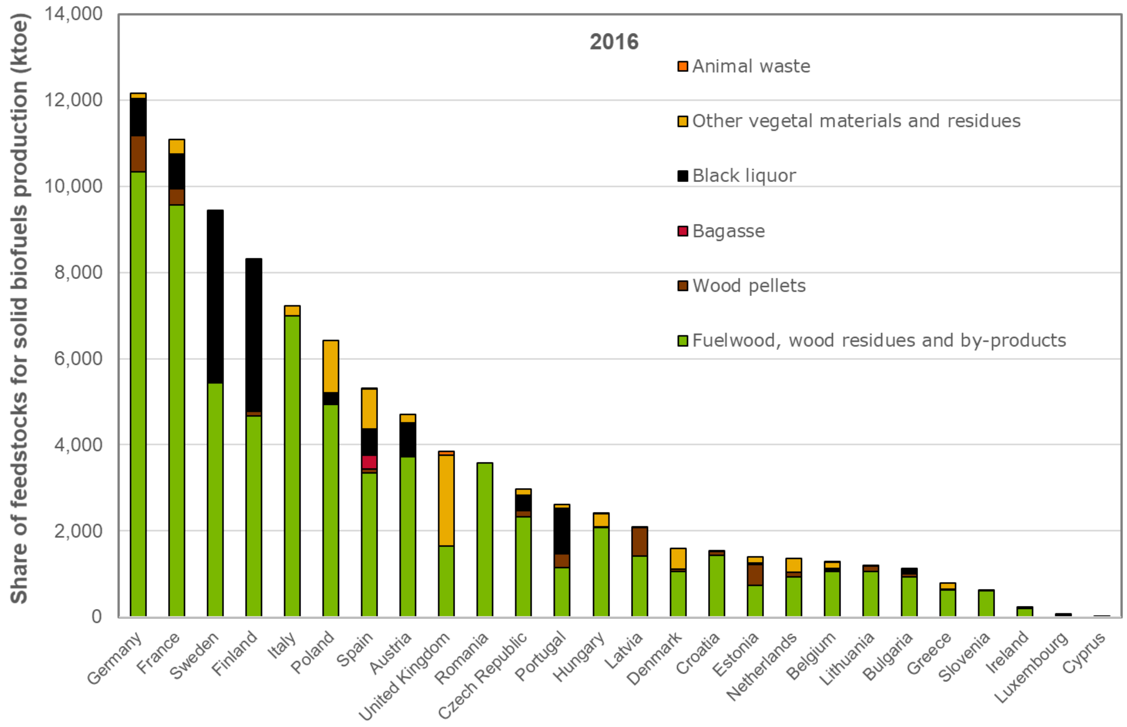

Figure 11. Share of feedstocks in the primary production of solid biomass in the EU28 per Member States (2016). Member States sorted by production volume [Eurostat nrg_109a data on "solid biofuels"[49]].

Origin of solid biomass[56]

As explored 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 8% (8 Mtoe) of its total consumption in 2016.[57] Compared to the solid biomass available within the EU, however, imported biomass could have larger environmental impacts, because the production is not subject to the EU and national sustainable forest management laws and standards. Therefore, it is important to understand the origin of solid biomass imported to the EU. This is done using a trade analysis approach, as described below, based on Eurostat international trade statistics.[58]

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

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[56] Only Eurostat is used to assess the total EU import of solid biomass, the major EU importers and the countries of origins, since the relevant data from the 2017 Member State's reports is incomplete. For example: the feedstock origins and imports in the UK's report are missing; Belgium included biomass supply data for only 2011 and 2012. Moreover, the reports do not indicate the countries of origins.

[57] In the same year the EU export of solid biomass was about 3.9 Mtoe (Eurostat nrg_107a). 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.

[58] 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

data for bagasse, black liquor, other vegetal materials and residues and animal waste are not included in the Eurostat International Trade statistics. A significant amount of animal wastes is imported to the EU28 according to Eurostat, however, the statistics do not provide specific information on the share of imported animal wastes in the solid biomass market. In the following sections we provide details on the imports of wood pellets and wood chips.

Wood pellets import

Figure 12 shows the EU wood pellets imports between 2015 and 2017. The EU imported 8,692 ktonne of wood pellets for energy use in 2017[59]. This represents an increase of almost 22% compared to 2015. Figure 12 also shows the EU's main trade partners between 2015 and 2017. These seven countries account for more than 97% of the wood pellet imports to the EU since 2015. The overall composition of the EU's main trade partners in this period remains the same with some changes in the import trend. The United States has been the largest exporter to the EU (accounting for almost 60% of the import in each year), followed by Canada (almost 20% in each year) and Russia. Imports from Russia increased by about 61% from 786 ktonne in 2015 to 1,269 ktonne in 2017. Other changes in the import trend can be seen in imports from Bosnia (decreased by 47% point from 135 ktonne in 2015 to 71 ktonne in 2017) and Brazil (increased by more than fourfold from 23 ktonne in 2015 to 103 ktonne in 2017).

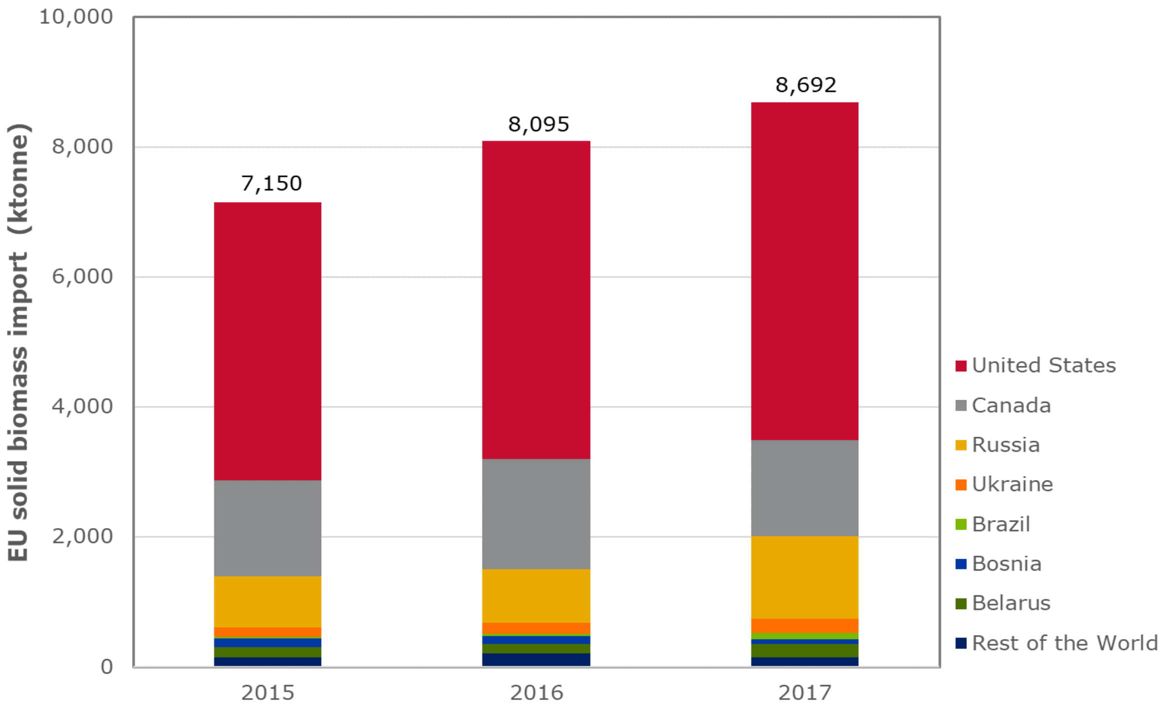

Figure 12. EU wood pellets imports from the main EU trade partners between 2015 and 2017 [Eurostat trade statistics on wood pellets CN 44013100[60]].

[59] This information excludes intra-EU imports and indicates only imports from outside the EU28 borders.

[60] 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").

Figure 13 presents the top Member States of wood pellets imports in 2017. The UK has been the most significant importer of wood pellets in the EU since 2015. In 2017, the UK accounted for 68% of the total EU import followed by Belgium (11%), Denmark (9%) and Italy (4%) (Figure 13). Countries such as Germany, France and Sweden represented only a small share of the EU import (collectively <4%) while these countries were the largest consumers of solid biomass. The demand in these countries was mainly met by domestically produced solid biomass.[61] This is in line with the information reported by the Member States in their Progress Reports (see Appendix B).

The UK Member State Progress Report does not give details on the sources of biomass for heat and electricity production. Offgem Biomass Sustainability Datasets for 2015-16 and 2016-17 show that 23-32% of the solid biomass for power production was imported from the USA and 9-12% from Canada.[62] For 18-35% the source was unknown. Note that 22-29% of the bioenergy used in UK power generation still originated from the UK and the remainder from other EU Member States.

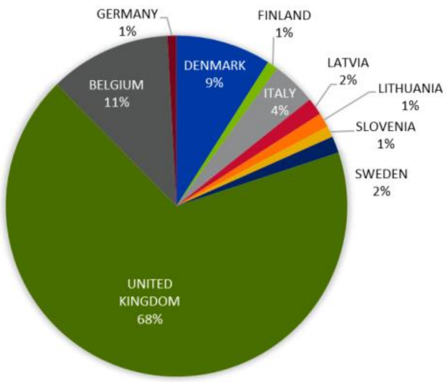

Figure 13. EU top importers of wood pellets in 2017, [Eurostat trade statistics on wood pellets CN 44013100].

Wood chips import

Figure 14 presents the EU import of wood chips in the period 2015 and 2017. The figure shows that the EU imported 4,868 ktonne of wood chips in 2017[63]. This represents an increase of almost 25% compared to 2015. The figure also shows the EU's main trade partners between 2015 and 2017, of which Russia and Belarus are the most important ones in terms of size. The seven countries identified in the figure account for more than 97% of the wood chips imports to the EU since 2015. 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 has been the largest exporter to the EU (accounting for more than 32% of the import of wood chips in each year), followed by Belarus (almost 30% in each year) and Uruguay. The most significant changes in imports trends can be seen in the imports from Chile. While in

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").

[61] Eurostat database, nrg_107a

[62] The ranges represent values found in the 2015-16 and in the 2016-17 Biomass Sustainability Datasets, published by Offgem.

[63] We cannot verify whether the entire imported woodchips 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.

2015 and 2016 the imports from Chile were less than one ktonne, in 2017 this amount increased to 147 ktonne of woodchips. Imports from Russia, as the largest EU wood chips trade partner, increased by about 16% from 1,390 ktonne in 2015 to 1,617 ktonne in 2017, following the overall trend of an increase in wood chips to Europe.

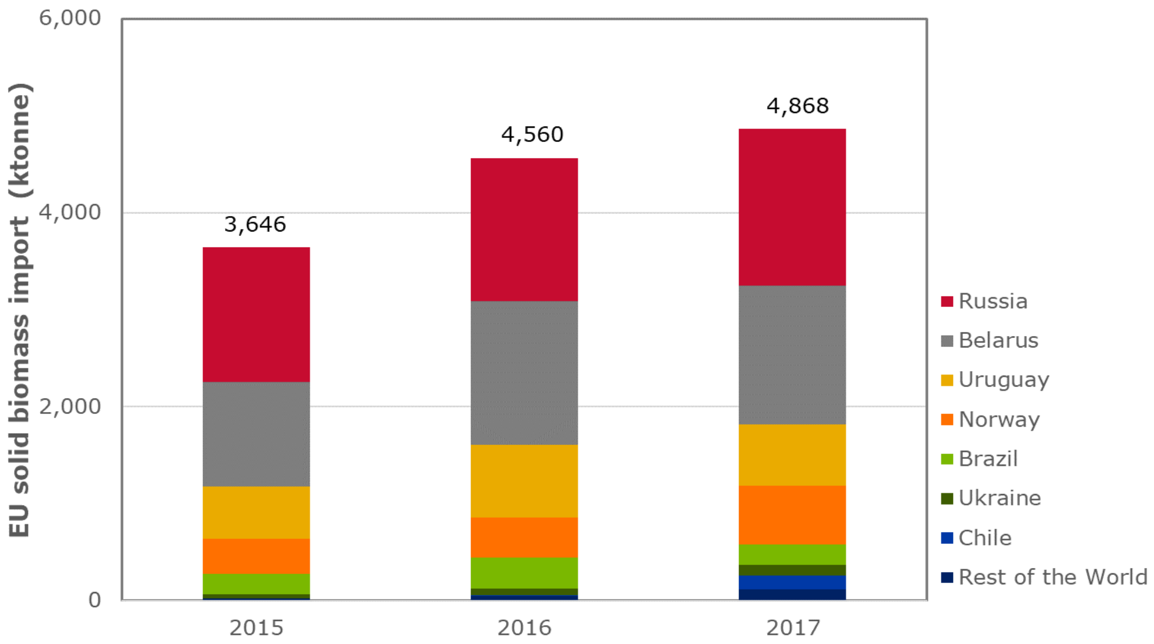

Figure 14. EU woodchips imports from the main EU trade partners between 2015 and 2017 [Eurostat trade statistics on woodchips CN 44012100 and CN 44012200[64]].

Figure 15 shows the top Member States who imported wood chips in 2017. The figure shows that more than 90% of the total amount of wood chips imported to the EU took place through five Member States, namely Finland, Portugal, Poland, Lithuania and Sweden. Finland was the largest importer of wood chips and accounted for 32% of the total EU wood chips imports in 2017. Portugal and Poland each imported about 18% of the total share and with that were the second and third largest EU importers of woodchips (Figure 15).

[64] 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)

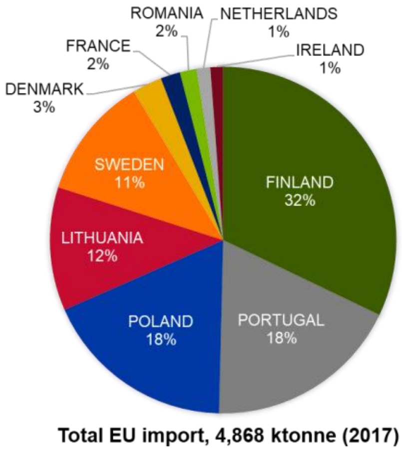

Figure 15. EU top importers of woodchips in 2017, [Eurostat trade statistics on woodchips CN 44012100 and CN 44012200].

3.2 Biogas

Consumption of biogas for energy in the EU

Biogas is the second largest form of bioenergy in the EU representing a 12% share of all primary bioenergy, or 16.6 Mtoe. It is used to produce 3.6 Mtoe of heat and 5.4 Mtoe of power (see Figure 2 in Chapter 2). The difference between these numbers, of 7.6 Mtoe, are losses, especially due to the efficiency of power production. In 2016, biogas is usually consumed (for heat or power production) close to its production location. The electricity is typically fed into the national grid. 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. However, the use of upgraded biogas (biomethane) in transport is still very marginal in the EU and accounted for less than 1% of the total biogas market in 2016. In 2016, the EU consumed 130 ktoe of biogas in transport, of which 98.9 ktoe was used in Sweden and 31.8 ktoe in Germany. The high consumption in Sweden was driven by energy and CO_2 tax exemptions for biomethane in transport.

Production 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,[65] 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

[65] 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].

both outputs in a CHP system. Biogas can also be upgraded to biomethane,[66] a process in which the carbon dioxide, water and other trace gas impurities are removed. Biomethane has an additional advantage, namely that it can be injected into existing gas infrastructure or used as a transport fuel.

The number of biogas plants in the EU increased from 12,397 installations in 2011 to 17,439 in 2016.[67] As a result the production of biogas also strongly increased over this period, as indicated in Figure 16. The total biogas production in the EU was 16,600 ktoe in 2016, which represents a 56% growth since 2011 (10,612 ktoe). Figure 16 shows the 10 largest EU biogas producers. Germany has been the frontrunner in biogas production to date accounting for ~49% of the total EU production in 2016, followed by the UK (15.6%), Italy (11.2%), France (4.5%) and the Czech Republic (3.6%).

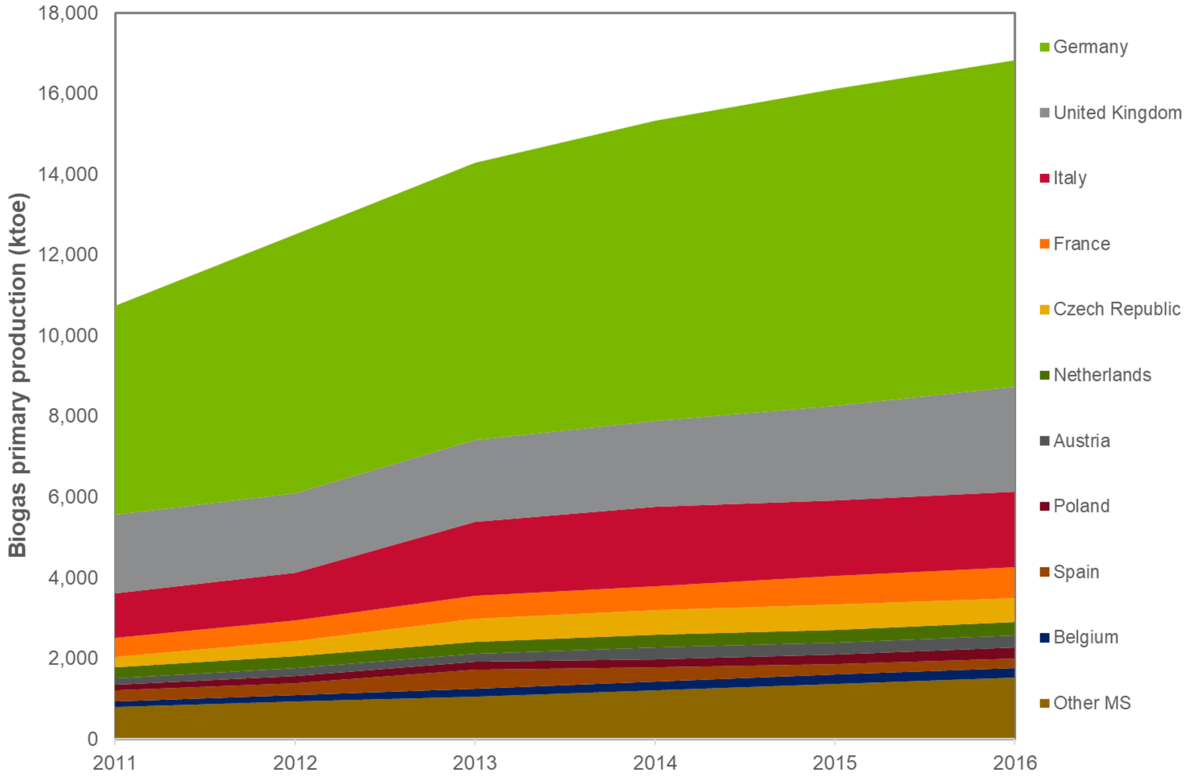

Figure 16. Biogas production in the EU28 between 2011 and 2016. Data are shown for the 10 Member States with the largest production volume in 2016. The other Member States are aggregated [Eurostat nrg_107a].

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[66] 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].

[67] European Biogas Association (EBA): http://european-biogas.eu/2017/12/14/eba-statistical-report-2017-published-soon/

The production of biogas is assessed in more detail in Figure 17. This figure again shows that Germany produces much more biogas than any other Member State. Germany mainly produces biogas from manure and energy crops like corn silage, but also a significant amount from sewage sludge. Italy also produces mainly from manure and energy crops, with a small contribution from landfill gas. The production of biogas from landfills is largest in the UK.

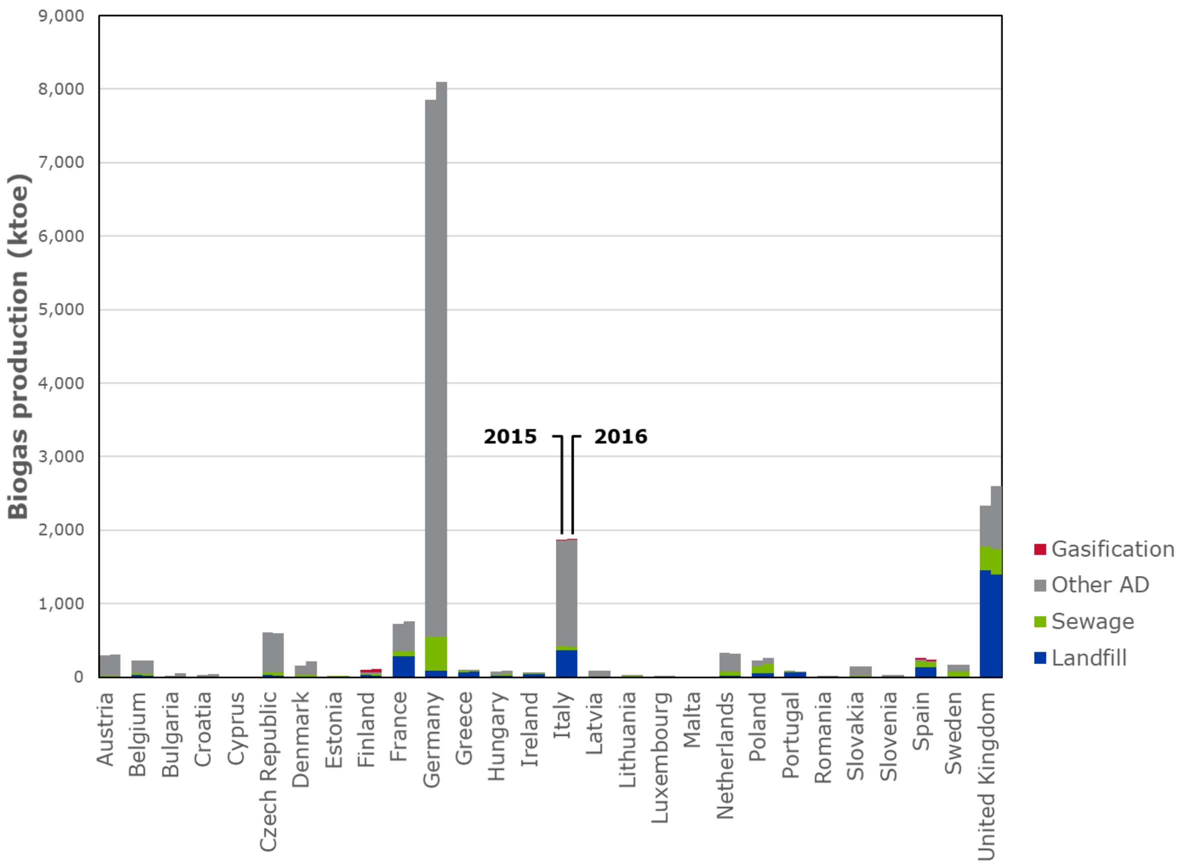

Figure 17. Biogas production per Member State, from different sources, in 2015 and 2016 [Eurostat nrg_109a]. "Other AD" stands for "Other biogases from anaerobic fermentation" and mainly represents biogas from manure and energy crops like corn silage.

Biogas production in the EU has two main purposes: it is either seen as a method for waste treatment, a way of energy production, or a combination of the two. Member States have structured their incentives accordingly, to favour different feedstocks. [68] 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.[69] The most effective driver for the production of

[69] 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

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, changes to the Renewable Energy Act in 2012 and 2014 reduced the attractiveness of new biogas plants due to reduction of the support tariffs. 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 the Czech Republic, 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. In France, the increase in biogas production has been driven by investment support and a feed-in tariff.[70] In the Netherlands, low electricity prices have led to a reduction in biogas for electricity generation in 2016.[71]

Table 7 shows biogas production in the EU between 2011 and 2016, differentiated by feedstock types.[72] 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 other hand, biogas production from anaerobic digestion and thermal processes increased. The increase in biogas from anaerobic digestion is due to the installation of more digesters, notably in Germany, Italy and France.[73] In 2016, biogas from farm-based plants (mainly silage maze), manure and other agro/industrial organic wastes had a share of 75%, whereas biogas from landfill had a share of 16% and biogas production from sewage sludge had a share of 9%. In Germany, the largest EU biogas producer, 93% of biogas is produced from anaerobic digestion of agriculture wastes, residues and crops (manure, corn and hay silage and sugar beet). In the UK, the second largest EU biogas producer, around 32% of biogas is produced from agricultural products and the biggest share (around 67%) comes from landfill and sewage sludge gases.

The share of biogas from thermal processes was less than 1% since these technologies are still in an early development stage.

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[70] Optimal use of biogas from waste streams, the European Commission, 2016: https://ec.europa.eu/energy/sites/ener/files/documents/ce_delft_3g84_biogas_beyond_2020_final_report.pdf

[71] Already since 2000, **Germany** has attractive feed-in tariffs for renewable electricity produced from (amongst others) biogas. The system provides good Transparency, Longevity and Certainty (TLC) to investors and has led to the development of over 9,000 biogas production facilities, although it should be noted that most development took place before 2011 and growth is levelling off now [Fachverband Biogas, Biogas market data in Germany 2016/2017]. In Italy, renewable electricity (including biomass) is promoted through a number of feed-in and premium tariffs. Depending on the plant size and the sources, plant operators can chose between the available tariffs or may be obliged to opt for a certain system. The feed-in tariff system is in place since 2016. Moreover, a price-based system (Conto Termico)is in place in Italy to promote renewable heat (including biomass) [legal sources on renewable energy, http://www.res-legal.eu/search-by-country/italy/]. In the United Kingdom, renewable heat (including biogas) is supported by a subsidy and price-based mechanism while renewable electricity is promoted through a combination of several schemes including feed-in tariff, Contracts for Difference, Renewable Obligation, a certificate and a tax mechanism [legal sources on renewable energy, http://www.res-legal.eu/search-by-country/united-kingdom/]

[72] 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

[73] USDA Foreign Agricultural Service, EU biofuels annual 2017

Table 7. Biogas production from various feedstock sources in the EU, in ktoe [Eurostat, nrg_109a]

Product	2011	2012	2013	2014	2015	2016
Biogas from crops and agro/food waste [1)]	6,537	8,298	9,770	10,866	11,674	12,388
Biogas from landfill gas	2,867	2,814	2,880	2,805	2,750	2,677
Biogas from sewage sludge gas	1,186	1,214	1,391	1,381	1,393	1,455
Biogas from thermal processes	21.9	27.7	61	67.1	69.2	79.8
Total biogas	**10,612**	**12,354**	**14,102**	**15,119**	**15,889**	**16,600**

1) Eurostat nrg-109a 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.

Origin of biogas and its feedstocks

Nearly all the biogas that was produced in the EU has been consumed domestically.[74] 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 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

Bioliquids account 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 an increasing trend in the use of bioliquids in the EU. Bioliquids for electricity generation were only deployed in four Member States: Italy (398 ktoe), Germany (40 ktoe), Belgium (3 ktoe) and Austria (<1 ktoe).[75] Whereas in Italy bioliquids account for a large share of domestically produced bioelectricity (~27%), in Germany, Belgium and Austria they only account for a very small fraction (<1% 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. For the same reason, the Member States' Progress Reports do not split between feedstock used for biofuels and bioliquids and they are often listed under the same category. In the case of Italy, bioliquids used for heat and electricity generation were reported "to be pure palm oil and rapeseed oil, other bioliquids (from plant or animal waste[76]) and biodiesel."[77] The exact origin is unknown.

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[74] Eurostat nrg_107a

[75] Data were obtained from Member State's reports, submitted in 2018.

[76] We interpret this as waste vegetable oil, or UCO, and animal fat.

[77] Annex II of Italy's Fourth progress report under Directive 2009/28/EC, 2018.

3.4 Liquid biofuels

The consumption of liquid bioenergy carriers in the EU accounts for 15.1 Mtoe, or 11% of all bioenergy, or 7.0% of all renewable energy (in all sectors). Liquid bioenergy largely concerns biofuels in transport (13.7 Mtoe) and for a smaller part bioliquids, i.e. liquid forms of bioenergy used for power production in conventional thermal power stations (1 Mtoe) and of heat and power in CHP stations (0.3 ktoe). The part of bioliquids is further described above in Section 3.3 Because the sustainability of bioenergy in the frame of the Directive especially concerns biofuels in transport, their feedstock and origin are assessed in more detail in Chapter 4.

3.5 Renewable fraction of municipal solid waste

The contribution of the renewable fraction of municipal solid waste (MSW) to the gross bioenergy consumption is 7.4% in 2016, see Figure 2 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 10.3 Mtoe in 2016. MSW is currently only used to produce heat (3 Mtoe according to Eurostat,[78] although not reported by Member States in their Progress Reports) and power (net 1.8 Mtoe renewable electricity). Germany, France and the Netherlands have continuously been the major 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 2011 in all of the main Member States. Germany shows a constant and rapid growth over time (24% between 2011 and 2016), the UK shows a jump from 2014 and other Member States show almost a constant consumption with slight fluctuations over time. In 2016, Germany was by far the largest consumer of MSW for power generation, accounting for 30% of the EU consumption followed by the UK (13%), Italy (11%), France (10%), the Netherlands (9.5%) and Sweden (8%).

[78] Eurostat nrg_106a reports that the gross heat production from the renewable fraction of municipal solid waste in the EU in 2016 was 3 Mtoe. This is not visible in Figure 2, since heat in Figure 2 is based on Member State reports as explained in Footnote 15.

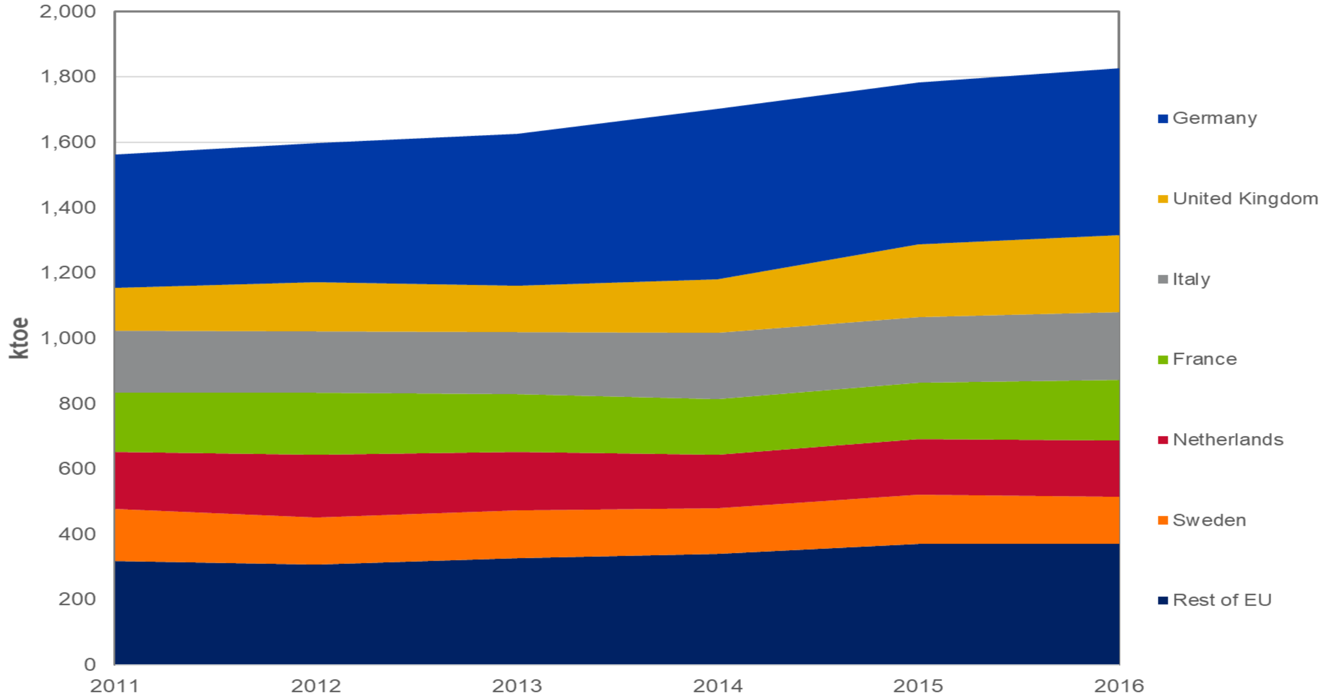

Figure 18. Historical consumption of Municipal Solid Waste (MSW, renewable fraction) in the power sector in the main EU consumers.

Table 21 in Appendix A, gives an overview of the information reported by the Member States on the share of biodegradable waste in 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 shown, several Member States did not report the actual share they applied in 2015/2016. Additionally, several Member States did not report any renewable energy produced from MSW (e.g. Bulgaria, Cyprus, Greece, Latvia and Slovenia), while others did report renewable energy produced from MSW, but not the fraction applied (e.g. Austria, the Czech Republic, Ireland, Lithuania, Luxembourg, Poland and Spain). 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 share of biodegradable waste in 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.[79]

[79] 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

Most biofuels consumed in the EU constitute of biodiesel (FAME or HVO) or bioethanol.[80] The contribution of methanol is small, while the contribution of other forms of biofuels is not reported. Almost all biofuels are consumed in the road transport sector, while the use in aviation and shipping is negligible. About 40% 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. The limited increase in volume results from the introduction of double counting biofuels, which increased the administrative deployment of renewable energy in transport, while it partially replaced existing single counting biofuels.

About 64% of the biodiesel consumed in the EU in 2016 comes from EU feedstock, mainly from rapeseed (38%) and from used cooking oil (13%), animal fat (8%) and tall oil (2.5%). The main third countries of origin are Indonesia (14%) and Malaysia (7%) whose palm oil ends-up in EU consumed biodiesel.

At least 65% of the bioethanol consumed in the EU in 2016 comes from EU feedstock. This mainly concerns wheat (25%), corn (22%) and sugar beet (17%). Also, there is a significant contribution of corn from Ukraine (9%).

Biodiesel (FAME and HVO)

The EU is the world's largest biodiesel producer followed by the US. Biodiesel represents the majority of biofuels in the EU, with a share of about 80% of the total transport biofuel market (compare Figure 19 and Figure 20).[81] Figure 19 shows biodiesel consumption in the EU between 2011 and 2016. 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 2016 roughly 80% concerns FAME and 20% concerns HVO. With increasing HVO production in France (Total) and Italy (ENI) this figure is expected to shift to 70/30 in the coming years. The figure presents the 10 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 in the past five years, 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

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[80] 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".

[81] Eurostat data, nrg_107a

an increasing RES-T share over the same period, while the biofuels volume in total hardly increased. This was discussed in Section 2.3

The following trends can be observed from Figure 19:

- A rapid biodiesel uptake is observed between 2011 and 2012 in most of the large 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%.[82]
- 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.[82]
- 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 use fluctuated as mandate increases in some Member States[82] were off-set by consumption decreases in other Member States. During this period, the biodiesel consumption decreased in Germany, the UK, and the Czech Republic 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 the Czech Republic an increase in the excise tax for biofuels made biodiesel more expensive compared to fossil diesel.[83] In Sweden, biodiesel consumption benefitted from tax exemptions and higher mandates for biofuels in diesel (19.3% on energy basis).[84]

Biodiesel (FAME & HVO) consumption is driven almost exclusively by Member State mandates.[85]

[82] Overview of the biofuel policies and markets across the EU-28, ePURE, 2016.

[83] Czech Republic case study, European Environment Agency:

[84] https://green-budget.eu/green-overhaul-of-swedish-fuel-and-vehicle-taxation/

[85] See ‘Technical assistance in realisation of the 4th report on progress of renewable energy in the EU’, Ecofys 2018

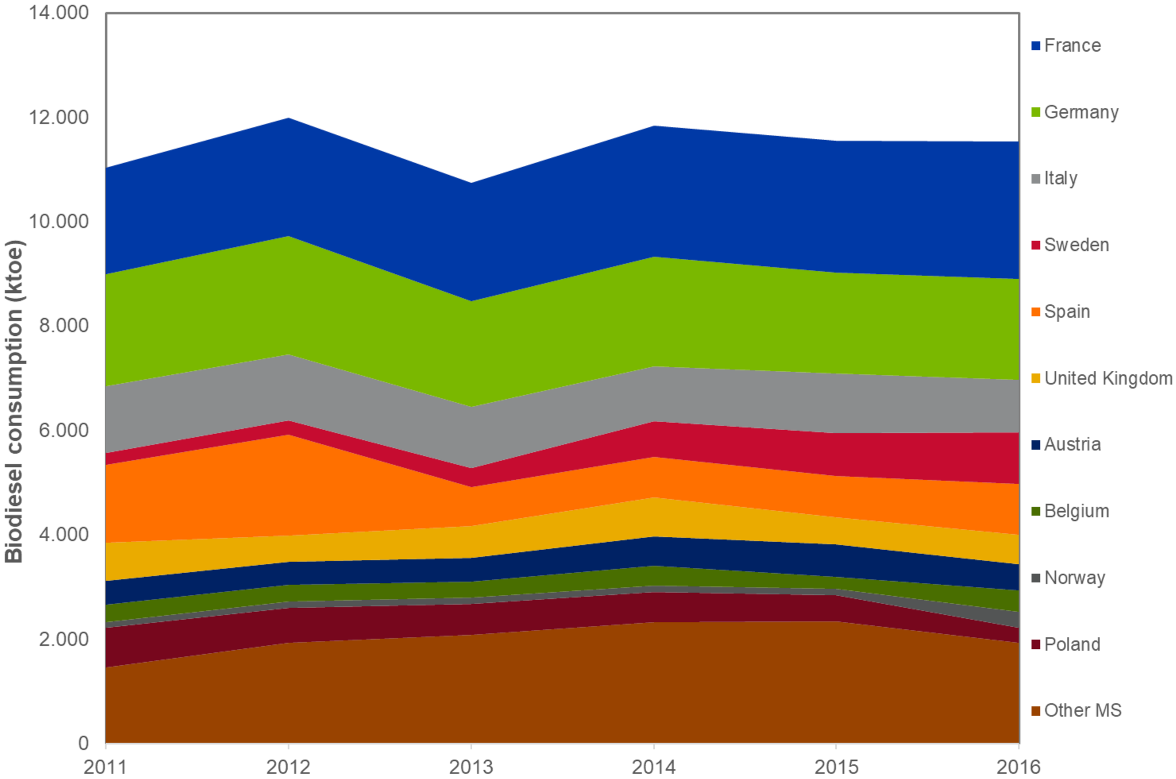

Figure 19. Biodiesel consumption in the EU28 between 2011 and 2016; Data are shown for the 10 Member States with the largest consumption volume in 2016; The other Member States are aggregated [Eurostat nrg_107a].

Bioethanol (ethanol and ETBE)

Figure 20 shows bioethanol consumption in the EU between 2011 and 2016. The figure shows the 10 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 since 2011. 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[86] (115 million litres in 2011 vs 102 million litres in 2016) and the adjustment of national bioethanol specific blending mandates.

The growth of bioethanol consumption was also limited by the existence of a “blend wall”, i.e. the technical and economic challenges of expanding the fraction of bioethanol in regular gasoline beyond a certain blend level. Sales above this level are only possible in niche markets, such as E85 (85% ethanol/15% gasoline) for flex-fuel vehicles, or E100 (neat ethanol) for converted gasoline engines. Historically, the level of bioethanol in mainstream gasoline was limited to 5% by volume by EU fuel quality standards. With the implementation of the Fuel Quality Directive, the

[86] Eurostat database

share of ethanol in mainstream gasoline is limited to 10% by volume. Since 2009, E10 (10% bioethanol by volume in gasoline) has been successfully introduced in France, with a 20% market share in 2012. However, its introduction in Germany in 2011 was less successful because consumers were concerned that E10 might ruin their car's engine. After improving communication, an increased uptake was observed; as of February 2014, the market share of E10 in Germany was 15%.[87]

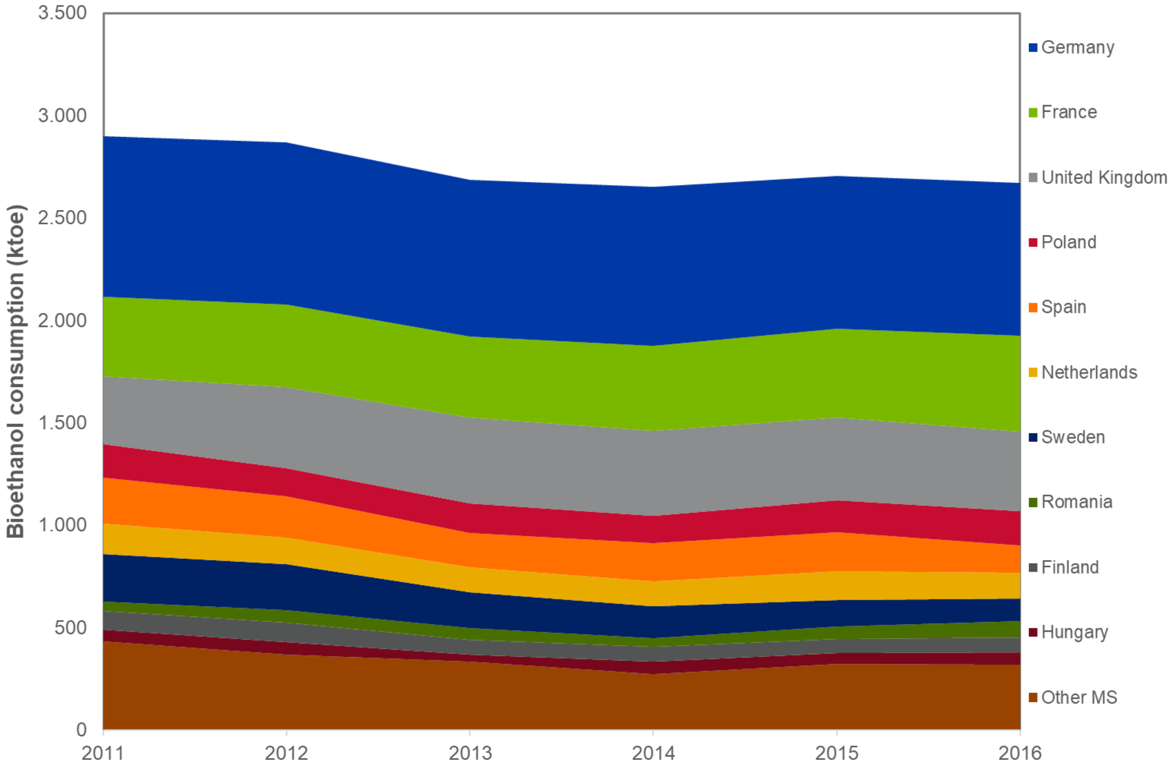

Figure 20. Bioethanol consumption in the EU28 between 2011 and 2016; Data are shown for the 10 Member States with the largest consumption volume in 2016; The other Member States are aggregated [Eurostat nrg_107a]. NOTE: Eurostat reports the consumption of biogasoline. The largest part of this product is bioethanol or its derivative bio-ETBE.

[87] BDBe, 2014

4.2 Biofuels production in the EU

Biodiesel (FAME and HVO)

Figure 21 shows biodiesel production (FAME and HVO) in the EU between 2011 and 2016. The figure recognizes the 10 largest EU producers and separates them from the rest of Member States (presented in aggregated form). In 2016, about 79% (on mass basis) of the biodiesel produced in the EU was FAME biodiesel, and the remainder was HVO biodiesel.[88] FAME production facilities exist in almost every EU Member State except in Luxembourg and Estonia. In contrast, currently only five Member States (the Netherlands, Finland, Italy, Spain and Portugal) have operational HVO production facilities, with a combined capacity of 2.5 Mtonne (equal to 2,627 ktoe).[89]

The EU biodiesel market is mainly driven by domestic consumption and import competition. Although Germany was the largest producer in 2016, France was the largest biodiesel consumer in the same year (compare Figure 19 and Figure 21).

Figure 21 shows that biodiesel production in the EU had an increasing trend from 2011 – 2014, followed by a slow decrease towards 2016. In 2014, EU biodiesel production benefited from higher domestic consumption and higher exports.[90] As a result, biodiesel production increased in most of the Member States, most significantly in Spain, Belgium, the Netherlands, Germany and France.[91] 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 vs 6.6 Mtonne in 2014).[92]

[88] F.O. Licht database, world biodiesel balance

[89] https://www.greenea.com/wp-content/uploads/2017/02/HVO-new-article-2017-1.pdf

[90] Eurostat, nrg_136a

[91] Eurostat, nrg_107a

[92] Eurostat, nrg_126a

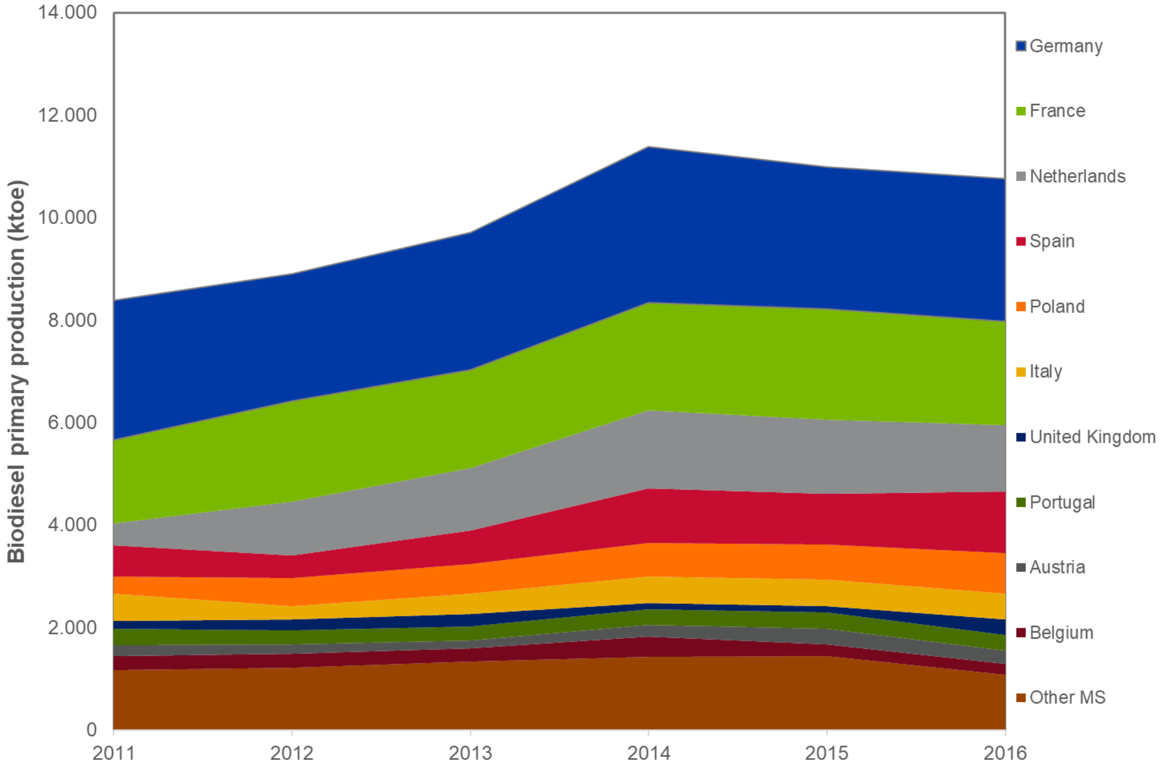

Figure 21. Biodiesel production in the EU28 between 2011 and 2016; Data are shown for the 10 Member States with the largest production volume in 2016; The other Member States are aggregated [Eurostat nrg_107a].

Bioethanol (ethanol and ETBE)

Although the EU is today the third largest bioethanol producer in the world, it remains a modest player with only 5% of the total global ethanol production in 2016[93]. Figure 22 shows bioethanol (ethanol and ETBE) production in the EU from 2011 through to 2016. The figure displays the 10 largest EU producers and separates them from the rest of Member States (presented aggregated). While EU bioethanol consumption has declined since 2011 (Figure 20), 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.

[93] F.O. Licht database, world ethanol top 20 balance

The decline from 2013 through 2015 is mainly due to a shrinking domestic market caused by lower consumption of gasoline and a downward adjustment of national bioethanol mandates. The production dropped most significantly in the UK, Belgium, the Netherlands and France.

In 2016, EU bioethanol production remained stagnant and is expected to increase from 2017 towards 2020 because of the increasing demands of Member States as they attempt to meet their 2020 RES-T targets.

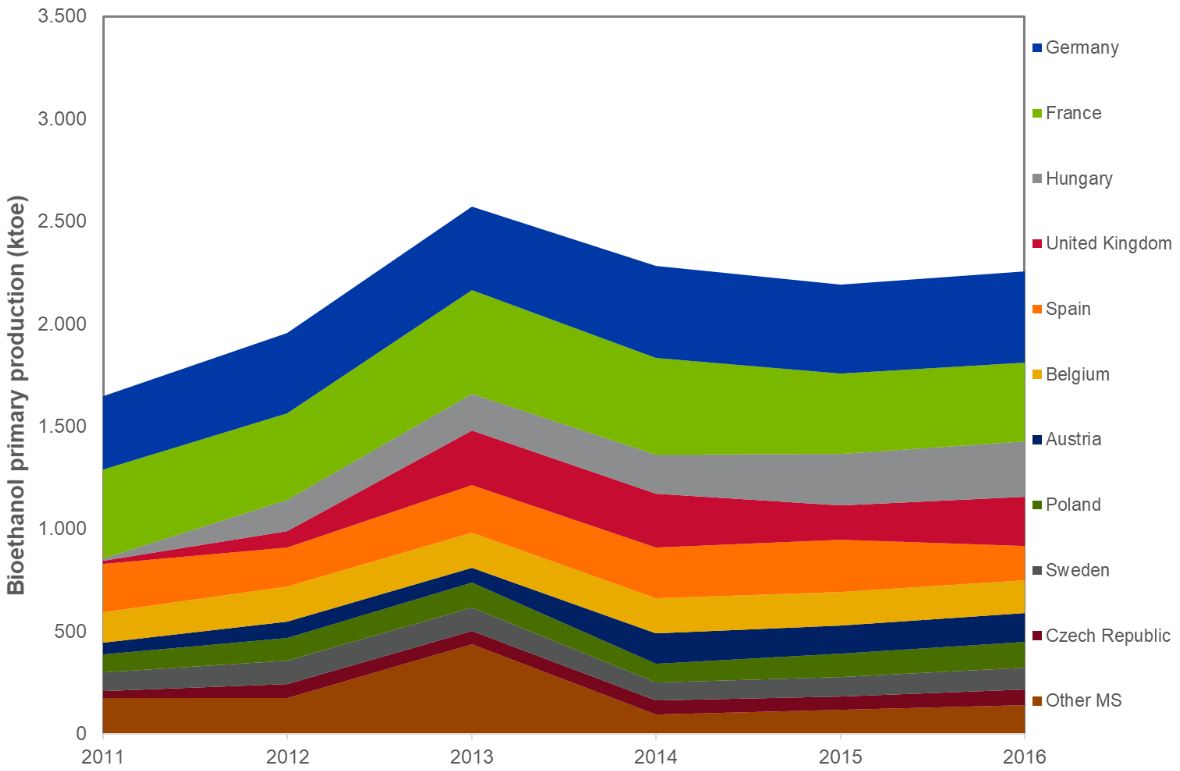

Figure 22. Bioethanol production in the EU28 between 2011 and 2016; Data are shown for the 10 Member States with the largest consumption volume in 2016; The other Member States are aggregated [Eurostat nrg_107a]. NOTE: Eurostat reports the consumption of biogasoline. The majority of this product is bioethanol or its derivative bio-ETBE.

4.3 Biofuels from wastes/residues or (ligno)cellulose

The use of waste streams or residues as feedstock for biofuels likely causes less sustainability impacts than traditional agricultural crops. Likewise, lignocellulose feedstock such as energy grasses could be produced with less sustainability impacts. 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 or animal fat.

Annex IX biofuels in the EU

“Advanced” or “waste-based” biofuels are often considered to have high greenhouse gas emissions savings (compared to fossil comparators) and zero or low indirect land use change (ILUC) impact. The ILUC Directive introduced a list of feedstocks which are commonly associated with these biofuels, in its Annex IX A.

The ILUC Directive includes a national subtarget of 0.5% for biofuels produced from Annex IX A feedstocks.[94] Part B of Annex IX includes a separate list of waste feedstocks (namely used cooking oil and animal fats categories 1 and 2). Biofuels produced from both Part A and 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 crop-based biofuels in transport.

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

- 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 one percentage point 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.[95]

[94] Member States shall endeavour to achieve the target and can also set a lower target if justified.

[95] Member States can set a lower target “taking into account best available evidence on ILUC impact” and differentiate by crop type.

Based on the above proposed elements and the EC support programs for the commercialization of Annex IX A biofuels,[96] 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 segment, this can be both FAME and HVO on the basis of used cooking oil or animal fats or HVO on the basis of tall oil. Other types of Annex IX A feedstock are not yet 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 planned projects and operational plants have already stopped. For example, in Italy, Beta Renewables[97] started commercial production of cellulosic ethanol (50 million litres per year) in Crescentino in 2013, with wheat straw, rice straw and husks and Arundo donax (an energy grass) as feedstocks.[98] However, the plant stopped operation in 2017, primarily due to the bankruptcy of its parent company.[99] In Finland, St1 Biofuels Oy in cooperation with North European Bio Tech Oy announced a cellulosic (sawdust-based) ethanol plant with an annual capacity of 10 million litres (with plans to expand to 50 million litres) to be operational in 2017, but there has been no production to date. Clariant is developing a cellulosic ethanol plant using agricultural residues in Romania, with an annual production capacity of 50 ktonne. The plant is expected to commence operation in 2020.[100]

Potential of Annex IX feedstock

The following table presents an overview of the potential (EU and global) of Annex IX feedstocks. The information in the table is collected from literature, statistical sources and publications by stakeholders where different approaches were taken in determining the estimates (e.g. actual production, theoretical potential, estimates based on market data).

[96] E.g.: Innovating for sustainable growth: a bioeconomy for Europe; Bio-based industries joint undertaking.
[97] Beta Renewables was a joint venture between Biochemtex, a company of the Italian Mossi Ghisolfi Group and the U.S. fund Texas Pacific Group (TPG).
[98] An energy crop grown on marginal land
[99] http://www.biofuelsdigest.com/bdigest/2017/10/30/beta-renewables-in-cellulosic-ethanol-crisis-as-grupo-mg-parent-files-for-restructuring/
[100] https://www.clariant.com/en/Corporate/News/2018/09/Groundbreaking-for-Clariantrsquos-sunliquidreg-cellulosic-ethanol-plant-in-Romanianbsp; http://www.biofuelsdigest.com/bdigest/2017/10/31/clariant-to-build-flagship-cellulosic-ethanol-plant-in-romania-8-figure-sales-potential-envisioned/

Table 8. Global potential for Annex IX feedstock.

Annex IX feedstock	Potential identified
(a) Algae	Global: 0.015 Mt/yr [1)] (China currently produces around 70% of global supply) [2)]
(b) Biomass fraction of MSW	EU: 138 Mt/yr [3)] Global: 1,195 Mt/yr (assuming a renewable/biomass fraction of 55%)
(c) Bio-waste from private households, separately collected	*Very diverse and specific per location*
(d) Biomass fraction of ind. waste	*Very diverse and specific per location*
(d) Fish fats	Key regions: EU (North Sea), South East Asia EU: 0.2 Mt/yr [4)] Global: Unknown
(e) Straw	**Cereal straw**: EU: 90 Mt/yr [5)] Global: 752 Mt/yr [6)] **Corn stover:** EU: 9-18 Mt/yr [7)] USA: 75 Mt/yr [8)]
(f) Manure	EU potential: 76 Mt/yr dry [9)] of which: - Solid manure (51 Mt/yr dry) - Liquid manure (25 Mt/yr dry) Global potential (Mt/yr): 1,600 (wet) [10)]
(f) Sewage sludge	In 2015: EU potential: 10 Mt/yr dry [11)] Global supply: 75 Mt/yr dry [12)]
(g) Palm oil effluent	The supply of POME was around 159 Mt in 2014 [13)]
(g) Empty fruit bunches	Global: 51-109 Mt/yr (mostly in Indonesia/Malaysia) [14)]
(h) Tall oil and Tall oil pitch	Key regions: North America, EU, Russia Global: 1.45 Mt/yr [15)] 0.14 Mt imported to EU from North America
(i) Crude glycerine	Key regions: EU, USA, South East Asia, South America Global: 3 Mt/yr [16)] EU: 1.15 Mt/yr [17)]
(j) Bagasse	Brazil: 163 Mt/yr India: 97 Mt/yr Global: 474 Mt/yr [18)]
(k) Grape marcs and wine lees	**Grape marcs [19)]** Global: 7.7 Mt/yr (key regions EU, Australia, USA) EU: 4.1 Mt/yr (centred on Spain, France, Italy) **Wine lees [20)]** Global: 1.5 Mt/yr (key regions EU, Australia, USA) EU: 0.81 Mt/yr (centred on Spain, France, Italy)
(n) Nut shells	Global: 10 Mt/yr (concentrated in US) EU: 0.8 Mt/yr (centred on Spain, Italy, Greece) [21)]
(m) Husks	Global: 120 Mt/yr EU: 0.5 Mt/yr [22)]
(n) Cobs cleaned of corn kernels	EU: 3.6 Mt/yr [23)]
(o) Forestry residues (thinnings, branches, tops, leaves and needles)	EU: 505 Mm3 (166 – pulp logs and low-quality logs,155 - sawmill residues, 76.5 - harvesting residues, 55 - bark) [24)]
(o) Forestry industry residues	
(p) Other non-food cellulosic material	
(q) Other ligno-cellulose material	
UCO	EU: 1.7-2 Mt/yr (2016) Global: 29 Mt/yr (2017), increasing to 34 Mt/yr (2022) – includes brown grease and gutter oil [25)]
Animal fat	EU: 2.78 Mt/yr [26)] Global: >10 Mt/yr [27)]

1) Algae Market, By Application, By Cultivation Technology, and Geography - Global Industry Analysis, Size, Share, Growth, Trends, and Forecast - 2016-2024, Transparency Market Research, 2016; https://www.prnewswire.com/news-releases/global-algae-market-is-projected-to-be-worth-us11-bn-by-2024-at-a-cagr-of-739-global-industry-analysis-size-share-growth-trends-and-forecast-2016---2024-tmr-594253011.html
2) State of Technology Review – Algae Bioenergy, IEA, 2017; http://www.ieabioenergy.com/wp-content/uploads/2017/01/IEA-Bioenergy-Algae-report-update-20170114.pdf
3) Based on data from Eurostat
4) Estimate based on European Aquaculture Production Report 2008-2016, FEAP, 2017; http://www.feap.info/Default.asp?SHORTCUT=582

5) Low ILUC potential of wastes and residues for biofuels: straw, forestry residues, UCO, corn cobs, Ecofys, 2013; https://www.ecofys.com/files/files/ecofys-2013-low-iluc-potential-of-wastes-and-residues.pdf and Crop production, Eurostat, 2018; http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=apro_cpnh1&lang=en
6) Advanced Biofuel Feedstocks – An Assessment of Sustainability, E4tech, 2014; https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/277436/feedstock-sustainability.pdf
7) Crop production in national humidity, Eurostat, 2018; http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=apro_cpnh1&lang=en and Perlack, R. D., & Turhollow, A. F. (2002). Assessment of options for the collection, handling, and transport of corn stover. ORNL/TM-2002/44, Report to the US Department of Energy, Office of Energy Efficiency and Renewable Energy, Biomass Program, http://bioenergy. ornl. gov/pdfs/ornltm-200244. pdf
8) US DoE & USDA (2005). Biomass as feedstock for a bioenergy and bioproducts industry: The technical feasibility of a billion-ton annual supply; https://www1.eere.energy.gov/bioenergy/pdfs/final_billionton_vision_report2.pdf
9) Outlook of spatial biomass value chains in EU 28, Elbersen et al., 2016
10) Live Animals, National Production, FAOSTAT, 2013; http://ref.data.fao.org/dataset-data-filter?entryId=c70af091-56be-41cc-8535-92c2ae460943&tab=data&type=Measure&uuidResource=c4876bcd-491f-4a4e-8c88-79d8889e3a89
11) Sewage sludge production and disposal, Eurostat, 2018. The supply and use/disposal values for the EU on slides 47 and 48 are 4 year averages, i.e. from 2012 to 2016; http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_ww_spd&lang=en
12) International Market Developments in the Sewage Sludge Treatment Industry, Avaccani & Partners, 2017; https://www.avp-group.net/wp-content/uploads/VDI-Conference-Sewage-Sludge-Treatment-20170517-Final-2.pdf
13) Annex IX factsheet – Municipal Solid Waste, UK Government, 2017; https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/277600/annexIX-factsheets.pdf
14) Annex IX factsheet – Municipal Solid Waste, UK Government, 2017; https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/277600/annexIX-factsheets.pdf
15) Own estimates
16) Estimate based on Leading biodiesel producers worldwide in 2017, by country (in billion liters), Statista, 2018; https://www.statista.com/statistics/271472/biodiesel-production-in-selected-countries/
17) European Biodiesel board, The EU Biodiesel Industry, 2016; http://www.ebb-eu.org/stats.php#
18) Bagasse, UNdata, 2018; http://data.un.org/Data.aspx?d=EDATA&f=cmID%3aBS%3btrID%3a01
19) Annex IX factsheet, UK Government, 2017; https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/277600/annexIX-factsheets.pdf
20) Annex IX factsheet, UK Government, 2017; https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/277600/annexIX-factsheets.pdf
21) Advanced Biofuel Feedstocks – An Assessment of Sustainability, E4tech, 2014; https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/277436/feedstock-sustainability.pdf
22) Annex IX factsheet – Municipal Solid Waste, UK Government, 2017; https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/277600/annexIX-factsheets.pdf
23) Low ILUC potential of wastes and residues for biofuels, Ecofys, 2013; https://www.ecofys.com/files/files/ecofys-2013-low-iluc-potential-of-wastes-and-residues.pdf
24) Estimates based on Pöyry's Wood database, Pöyry's Advanced biofuel data base and Eurostat; http://ec.europa.eu/eurostat/data/database
25) Analysis of the current development of household UCO collection systems in the EU, Greenea, 2016; http://www.theicct.org/publications/analysis-current-development-household-uco-collection-systems-eu and European Biomass Industry Association; http://www.eubia.org/cms/wiki-biomass/biomass-resources/challenges-related-to-biomass/used-cooking-oil-recycling/
26) Statistical overview of the Animal By- Products Industry in the EU in 2016, EFPRA, 2016. EFPRA has 29 members in 25 countries. The data is based on approximately >90% Cat 1, >80% Cat 2, >70% Cat 3 of the EU market); http://efprahamburg2017.com/wp-content/uploads/2017/05/Dobbelaere_Overview-on-the-EU-Animal-By-products-Processing-Industry-in-2016.pdf
27) National Renderers Association (NRA), Market Report – US Rendering a $10 billion industry, Render Magazine, 2017; https://d10k7k7mywg42z.cloudfront.net/assets/58e6bc07a0b5dd20940693af/MarketReport2016.pdf and Diagnosis of The Brazilian Rendering Industry, Brazilian Renderers, 2016; http://brazilianrenderers.com/en/views/downloads/II_Diagnostico_da_Industria_Brasileira_de_Reciclagem_Animal_-_EN.pdf and Supply of Animal Fats from A Buyer's Perspective, Apex Agricom, November 2017; https://www.iscc-system.org/wp-content/uploads/2017/05/12-Shanghai_November_2017_Chong.pdf

4.4 Geographical origin of feedstock for biofuels consumed in the EU

Feedstock for biofuels

The geographical origin of feedstocks used for biofuels consumed in the EU is derived by combining the biofuel trade statistics with estimations of feedstock for biofuels in all biofuel producing countries, as well as trade statistics of the major feedstocks. Table 9 and Table 10 present the estimated origin of the main feedstocks used to produce biodiesel and bioethanol as consumed within the EU. Table 9 shows that the majority of biodiesel by volume (64%) consumed in the EU market in 2016 is estimated to come from feedstocks produced in the EU, mainly from rapeseed (~38%), UCO (13%), animal fat (8%), tall oil (2.5%) and a small fraction that remains unknown. In 2016, additional UCO was imported from the USA, South East Asia and other countries. It is reported that in 2017, China starts playing an important role.[101] Tall oil is produced in countries such as Sweden and Finland where large pulp industries are in place. About 20% of the EU biodiesel volume originates from palm oil. We estimate that most of this palm oil biodiesel is produced in the EU from palm oil imported from Indonesia (13.3% of the EU consumed biodiesel) and Malaysia (4.1%), while a smaller fraction of the palm oil biodiesel (2.2% of the EU consumed biodiesel) is imported in the form of biodiesel from Malaysia.

Table 9. Origin of feedstock used for biodiesel as consumed within the EU in 2016.

	Rapeseed	Palm oil	Soybean	Tall oil	UCO	Animal fat	Unknown /other	Total	Total (ktoe)
EU	38.4%			2.5%	12.9%	8.0%	1.8%	63.7%	**7,062**
Australia	2.6%							2.6%	**287**
Ukraine	1.8%							1.8%	**202**
Canada	1.2%							1.2%	**132**
Indonesia		13.3%			0.7%			14.0%	**1,550**
Malaysia		6.3%			0.3%			6.6%	**734**
USA			1.5%		1.2%			2.6%	**293**
Brazil			1.5%					1.5%	**166**
Other	0.5%	0.0%	1.3% 1)		2.5% 2)		0.3%	4.6%	**510**
Unknown							1.3%	9.4%	**1,037**
Total	44.5%	19.5%	4.3%	2.5%	17.7%	8.0%	3.5%	100.0%	
Total (ktoe)	**4,929**	**2,166**	**474**	**281**	**1,959**	**891**	**385**		**11,083**

1) Smaller fractions of soybean biodiesel are estimated to originate from amongst others Canada (0.3%), Paraguay (0.3%), Uruguay (0.2%) and Ukraine (0.2%).
2) Smaller fractions of UCO based biodiesel are estimated to originate from amongst others Kuwait (0.8%) and Saudi Arabia (0.4%).

[101] Greenea (broker) indicates that in 2017 about 30% of the UCO used in Europe came from China. https://www.greenea.com/wp-content/uploads/2018/04/Greenea-Platts-Geneva-2018.pdf. Also the Member State progress reports do not give a clear indication of origin for UCO used. Ireland, Hungary and Greece indicate UCO used for their biofuels consumed is domestic, but Germany and Cyprus indicate an increased share of imported UCO (both from inside as well as outside Europe). The other Member States do not provide additional details regarding UCO. For more details on the information provided by Member States please see Appendix B.

Table 10 shows that about 65% of the bioethanol consumed in the EU in 2016 is estimated to stem from feedstocks produced in the EU, mainly wheat (~25%), corn (~22%) and sugar beet (17%) and only a small amount (~1%) from cellulosic ethanol. 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 35% of the EU bioethanol market, mainly corn originating from Ukraine, Russia, Brazil, Canada and the USA.

Table 10. Origin of feedstock used for bioethanol as consumed within the EU in 2016.

	Wheat	Corn	Barley	Rye	Triti-cale	Sugar beet	Sugar cane	Cellu-losic	Unknown /other	Total	Total (ktoe)
EU	24.7%	22.2%				17.0%		1.2%		65.1%	**1,696**
Ukraine	0.8%	9.0%								9.8%	**255**
Brazil		1.6%					0.2%			1.8%	**47**
Canada	0.4%	1.2%								1.6%	**43**
USA	0.5%	1.2%								1.7%	**44**
Russia	0.3%	1.7%								2.1%	**53**
Other	0.9%	1.7%					2.7%			5.3%	**137**
Unknown			3.0%	4.3%	4.9%				0.4%	12.7%	**330**
Total	27.6%	38.6%	3.0%	4.3%	4.9%	17.0%	2.9%	1.2%	0.4%	100%	
Total (ktoe)	**719**	**1,005**	**79**	**112**	**127**	**444**	**76**	**30**	**11**		**2,605**

Global biofuels trade

The share of biodiesel imported in the EU biodiesel market was relatively small in 2015 and 2016 and accounted for 6% and 5%, respectively. In 2016, all of this biodiesel (467.61 ktonne) was imported under UN/HS code 382600 containing at least 70% biodiesel. Figure 23 and Figure 24 show the global biodiesel trade in 2015 and 2016, respectively. The most notable observation from these two figures is the disappearance of import flows from Argentina and Indonesia. In 2011 and 2012, these two countries were the major exporters of biodiesel to the EU, with combined export volume of more than 2,500 ktonne per year (>88% of the total import to the EU).

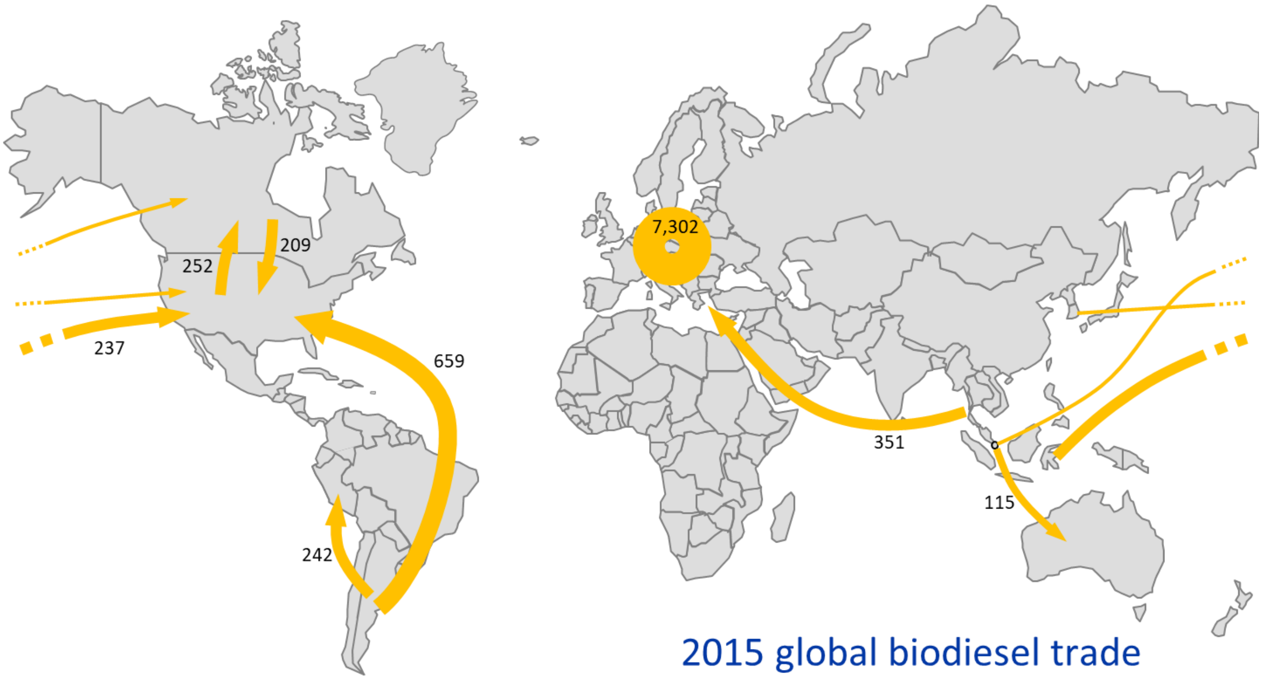

Figure 23. Global FAME biodiesel trade in 2015 in ktonne [Eurostat, Comtrade].

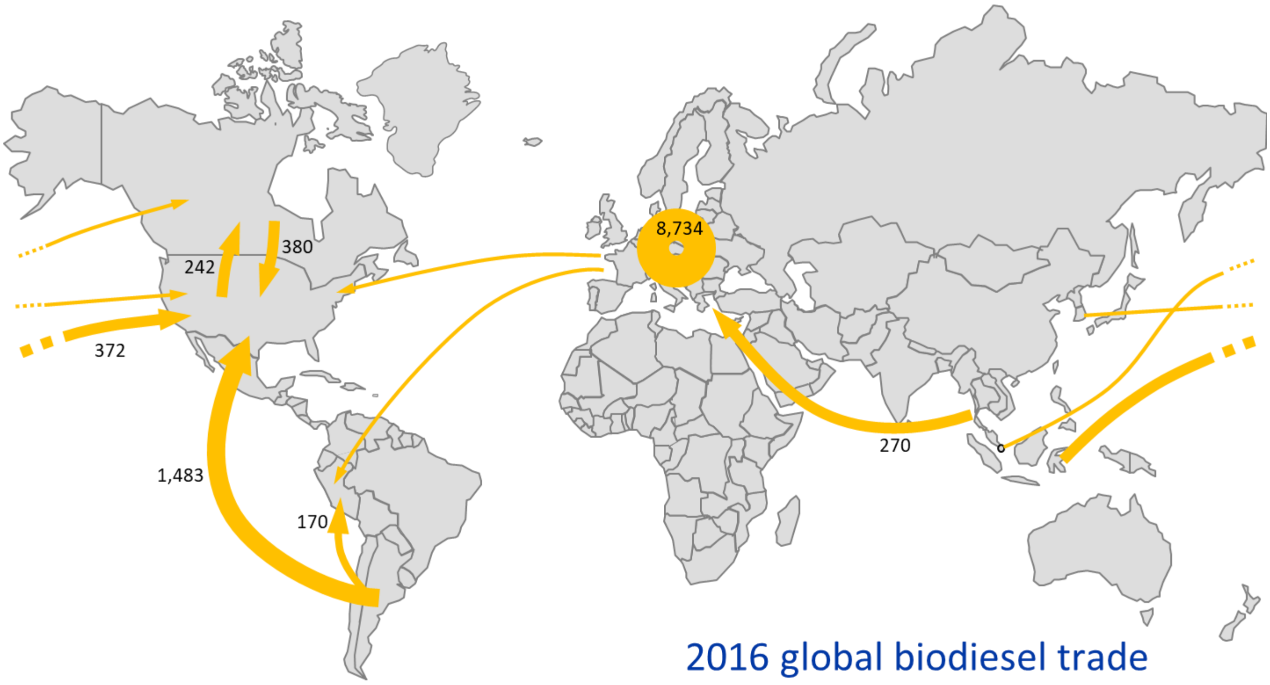

Figure 24. Global FAME biodiesel trade in 2016 in ktonne [Eurostat, Comtrade].

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 2016, the largest biodiesel exporter to the EU was Malaysia, supplying 269 ktonne or 57% of the total EU biodiesel import. Most of the biodiesel import occurred through the Netherlands (72%), followed by Spain (18%) and Italy (6%).

Figure 25 and Figure 26 show the global bioethanol trade in 2015 and 2016, respectively. In 2016 of the 4,140 ktonne (equal to 2670 ktoe) of ethanol in the EU, 10.5% was imported from outside the EU, showing a slight increase (~2%) compared to the year before. In 2015 and 2016, respectively, about 350 and 435 ktonne of ethanol was supplied to the EU through zero duty quotas. While the main suppliers in 2015 were Peru, Russia and Bolivia, in 2016 the supply mainly came from Guatemala, Peru and Pakistan. The EU ethanol import landscape has seen important changes since 2012. In 2012, imports accounted for 21% of the EU bioethanol 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 US. This resulted in the dumping of US 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 US exports of bioethanol to the EU from 522 ktonne in 2012 to 26 and 39 ktonne in 2015 and 2016, respectively.

EU bioethanol export to destinations out of the bloc has been less than 3% of the production.

The USA and Brazil were the largest global exporters of ethanol in 2015 and 2016. In total, the two countries exported more than 3,200 ktonne of ethanol per year. Aside from intra-trade between the two nations, the majority of the US and Brazil ethanol found its way to the Asian market, mainly in South Korea, Japan, Philippines, India and China.

It can be concluded that the international biofuel market is quite dynamic and trade routes change continuously. The production side is in particular volatile 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.

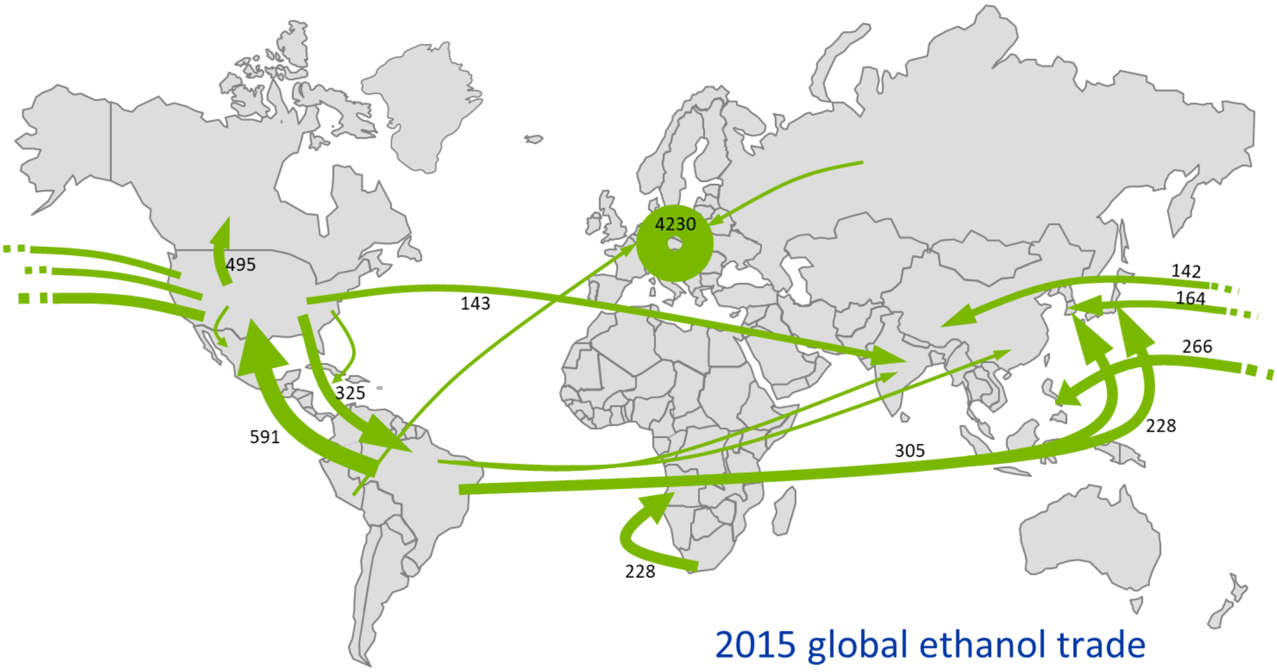

Figure 25. Global ethanol trade in 2015 in ktonne [Eurostat, Comtrade].

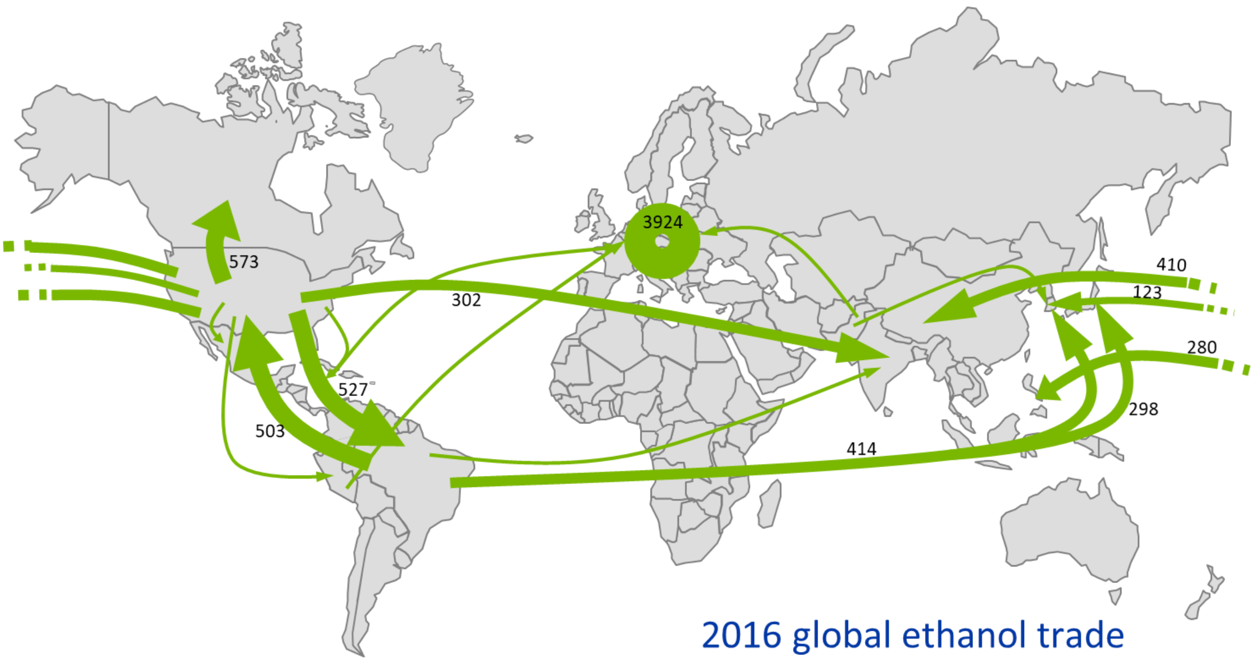

Figure 26. Global ethanol trade in 2016 in ktonne [Eurostat, Comtrade].

5 Environmental impacts related to biofuels

The Renewable Energy Directive obligates 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.

Most Member States have implemented measures to safeguard sustainability criteria in line with the criteria set out in the Directive. Only for Croatia, the status of implementation could not be assessed, since the progress report for Croatia was not available at the time the analysis was performed.

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 that was done in the previous chapter. Overall, it is estimated that 4.9 Mha of cropland globally, of which 3.6 Mha in the EU, has been used for the production of crops for EU consumed biofuels. 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.

On the basis of the crop-fuel volumes estimated in the previous chapter, the total greenhouse gas emission reduction from EU consumed biofuels in 2016 is estimated to be 28.4 Mtonne CO_{2eq}. This is likely an underestimation, because typical values from the Directive's Annex are used, while policies in several countries call for better-than-typical performance. On the basis of the Member State reports, the total emission reduction is indeed higher: 33.2 Mtonne CO_{2eq}. When the 2016 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 is reduced to 11.8 Mtonne of CO_2 savings (with a range from 7.4 Mtonne to 20.4 Mtonne of CO_2 savings). This is however an underestimation of savings, caused by an overestimation of ILUC, since in this estimation all biofuels consumed in Europe are assumed to have caused ILUC.

In recent years, several new studies on ILUC have been published. 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. Many impacts are safeguarded by the voluntary schemes. However, this may not completely avoid impacts, and a continued effort is needed to decrease impact and increase insights.

The majority of countries (Member States and main third countries) have ratified all relevant conventions on biodiversity and labour. Only the USA has ratified or accepted a limited number of 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.

5.1 Measures taken to respect the sustainability criteria for biofuels

National implementation of RED sustainability criteria and the ILUC Directive are presented in Table 11. Of the 28 Member States, 27 have implemented the Renewable Energy Directive's sustainability criteria in their national legislation. For Croatia, the assessment could not be done,[102] and also it was unclear from the previous assessment of the Member State Progress Reports if the sustainability criteria have been fully implemented in Croatia.[103] In the previous assessment Slovenia was also indicated as ´uncertain' with respect to the national implementation of the criteria. For Slovenia, the "decree on Sustainability Criteria for Biofuels and on Greenhouse Gas Emissions within the Lifecycle of Transport Fuels ULRS, No 38/2012" was implemented in 2012 already.

Seven Member States reported that they have implemented the ILUC Directive already in national legislation (see Table 11). Another five Member States mention that the implementation of the ILUC Directive is planned. The other 15 Member States have not mentioned the ILUC Directive, or its national implementation, in their Progress Reports.

[102] The Croatian Renewable Energy Progress Report was not yet available at the time of the assessment. Presently it is only available in the original language.

[103] Oeko-Institute commented ´no explicit mention of the Act, activities have been undertaken to fulfil the obligation to comply with sustainability requirements in the production and use of biofuels' [Oeko-Institut 2017, Study on Technical Assistance in Realisation of the 2016 Report on Renewable Energy, in preparation of the Renewable Energy Package for the Period 2020-2030 in the European Union. RES-Study Task 3: Analysis of the biofuels, biomass and biogas used for renewable energy generation].

Table 11. National implementation of RED sustainability criteria and ILUC Directive in the EU Member States according to Member State Progress Reports.

Member State	National implementation of RED sustainability criteria	National implementation of ILUC directive
Austria	Yes	Reported as 'planned/existing' amendment
Belgium	Yes	ILUC Directive not mentioned in Progress Report
Bulgaria	Yes	Procedure started to get amendment implemented (draft available)
Croatia	Unclear 1)	Unclear 1)
Cyprus	Yes	ILUC Directive not mentioned in Progress Report
Czech Republic	Yes	ILUC Directive not mentioned in Progress Report
Denmark	Yes	ILUC Directive not mentioned in Progress Report
Estonia	Yes	ILUC Directive not mentioned in Progress Report
Finland	Yes	Implemented July 2017
France	Yes	ILUC Directive not mentioned in Progress Report
Germany	Yes	Adopted in 2017
Greece	Yes	ILUC Directive not mentioned in Progress Report
Hungary	Yes	ILUC Directive not mentioned in Progress Report
Ireland	Yes	Indicates 'complying with ILUC Directive '
Italy	Yes	Implemented March 2017
Latvia	Yes	ILUC Directive not mentioned in Progress Report
Lithuania	Yes	Implemented July 2017
Luxembourg	Yes	Implemented 2017
Malta	Yes	ILUC Directive not mentioned in Progress Report
Netherlands	Yes	Implementation of ILUC Directive not completed at time of writing
Poland	Yes	ILUC Directive implemented January 2018
Portugal	Yes	No specific mentioning of ILUC Directive but they do mention a regulation to favour endogenous use of materials and waste
Romania	Yes	No updates related to ILUC Directive mentioned in the Progress Report
Slovakia	Yes	ILUC Directive not mentioned in Progress Report
Slovenia	Yes	ILUC Directive not mentioned in Progress Report. It only mentions that there is no clear definition yet for wastes and residues.
Spain	Yes	Mentioned as planned ('measures after 2017 – status planned')
Sweden	Yes	ILUC Directive not mentioned in Progress Report
UK	Yes	ILUC Directive not mentioned in Progress Report

1) The Croatian Renewable Energy Progress Report was not yet available at the time of the assessment. Presently it is only available in the original language.

5.2 Land use and land use changes

The land used for the production of feedstock for EU consumed biofuels, and the changes in this land use are estimated on the basis of 3 methods:

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.
3. An overview figure presenting land area used for cultivation of food and feed crops which are commonly used as feedstock for production of biofuels.

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 food/feed production both domestically and globally. In this report 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 2016 is estimated. This estimate covers, separately, lands that are used within the EU and in third countries, for the production of biofuels consumed in the EU. A methodology[104] based on combining the origin of feedstocks for biofuels production (as developed in Section 4.4) with country specific crop yields was applied. Co-products were accounted for by means of energy allocation in line with the greenhouse gas accounting rules of the Renewable Energy Directive.[105] 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, based on market averages, and insights into the trade of main biofuels and main feedstock, an estimate can be made.

Figure 27 shows how the land use for biofuel crops relates to other agricultural land use and the total surface of the country, for a selection of major countries of feedstock origin for 2016 EU consumed biofuels. The total amount of land required for the production of crops for EU biofuel (bioethanol and biodiesel) consumption in 2016 is estimated to be 4.9 Mha, based on the analysis of the origin of biofuels feedstock.[106] It is expected that this figure is higher than the actual land area because conservative data has been used for the conversion efficiencies and yields.[107]

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[104] This methodology was developed by Ecofys experts and was used in the Ecofys report for the European Commission on renewable energy progress and biofuels sustainability, published in November 2014.

[105] 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.

[106] The analysis of biofuels feedstock in Section 2.3 takes into account international trade in biofuels and their feedstocks, and conversion efficiencies. As an intermediate result, the amounts of feedstock involved per country of feedstock origin are calculated. This is combined with FAO data on crop yields per country.

[107] 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.

This figure is about 30% less compared to 2012 estimated land use for the EU consumption of biofuels (7.8 Mha[108]). An explanation for this reduction could be the lower biofuel consumption (see Figure 19 and Figure 20 in Section 4.1), or otherwise the increasing share of waste feedstocks (mainly waste vegetable oils and fats) for biofuels production.[109,110]

Of the 4.9 Mha land used for biofuels feedstock in 2016, 3.6 Mha (73%) is located within the EU and the remaining 1.3 Mha (26%) is located outside the EU. The EU has used 3.1% of its total cropland (total EU cropland is 115 Mha) for the production of feedstocks for biofuels. Rapeseed was the main crop used for biofuels production in the EU and represented 56% of the share of the total land used for biofuels production.

For countries outside the EU, the share of cropland that was estimated to be used for feedstock for EU biofuels is likely small. For all the selected countries (Figure 27) it is estimated that less than 0.5% of their total cropland was used for the extraction of feedstocks that were used in the production of biofuels consumed in the EU. Ukraine did not produce any bioethanol in 2016. However, 0.1 Mha of its cropland was used to produce maize that was converted outside of the Ukraine to bioethanol for the EU biofuels market. In Brazil, soybean production for biofuel makes up about 5% of the total land dedicated to soybean, but less than 0.5% is used for the EU biofuels market. Indonesia was estimated to use 1.3% of its palm oil cultivated land for biofuels that were consumed in the EU in 2016. However, it is noteworthy to mention that this share was significantly higher in 2012 (>6%).[111] The drop is likely to be a result of the combination of the considerable increase in total land used for palm oil cultivation (see the following section on 'historical development of land use for crops commonly used for biofuel production') 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 still EU producers could use imported palm oil. Malaysia, the largest biodiesel exporter to the EU in 2016, used less than 1% of its total palm oil cultivated land for biofuels that were consumed in the EU.

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[108] Ecofys report for the European Commission, renewable energy progress and biofuels sustainability, published in November 2014

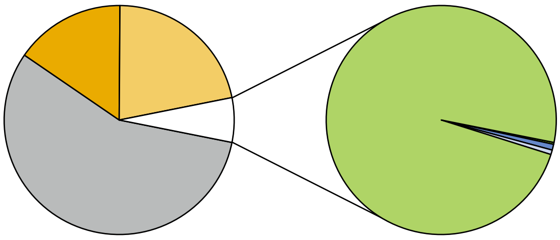
[109] Neste, the leading global HVO biodiesel producer used 70% waste oil as feedstock for biodiesel production: https://www.greenea.com/wp-content/uploads/2017/02/HVO-new-article-2017-1.pdf

[110] In Germany, the consumption of used cooking oil almost doubled, and in the Netherlands increased more than 20% over the period 2015 – 2016 [2016 Member State progress reports]

[111] Ecofys report for the European Commission, renewable energy progress and biofuels sustainability, published in November 2014

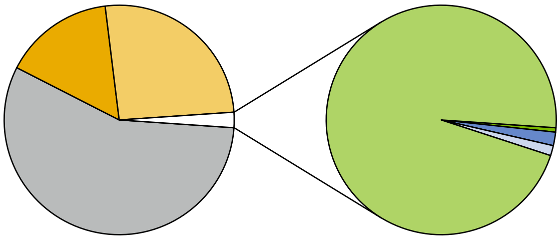
EU : wheat for bioethanol	2016
total land	410,477 kha
non-agricultural land	231,693 kha
meadows and pastures	63,706 kha
total land for wheat	25,800 kha
wheat for biofuel produced in EU, not for EU biofuel	69 kha
wheat for biofuel produced in EU, for EU biofuel	212 kha
wheat for EU biofuel produced outside EU	166 kha
wheat not for biofuel production in EU, not for EU biofuel	25,353 kha
other annual crops	89,278 kha

Total land — Land for wheat



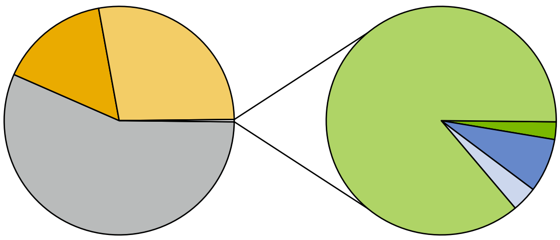
EU : maize for bioethanol	2016
total land	410,477 kha
non-agricultural land	231,693 kha
meadows and pastures	63,706 kha
total land for maize	8,889 kha
maize for biofuel produced in EU, not for EU biofuel	55 kha
maize for biofuel produced in EU, for EU biofuel	169 kha
maize for EU biofuel produced outside EU	127 kha
maize not for biofuel production in EU, not for EU biofuel	8,539 kha
other annual crops	106,188 kha

Total land — Land for maize



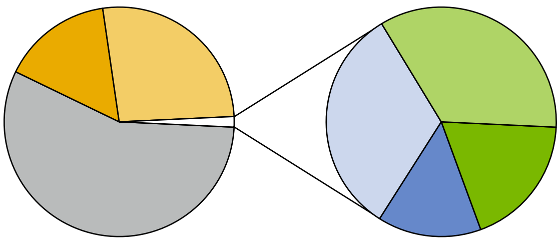
EU : sugar beet for bioethanol	2016
total land	410,477 kha
non-agricultural land	231,693 kha
meadows and pastures	63,706 kha
total land for sugar beet	1,351 kha
sugar beet for biofuel produced in EU, not for EU biofuel	34 kha
sugar beet for biofuel produced in EU, for EU biofuel	103 kha
sugar beet for EU biofuel produced outside EU	48 kha
sugar beet not for biofuel production in EU, not for EU biofuel	1,165 kha
other annual crops	113,727 kha

Total land — Land for sugar beet

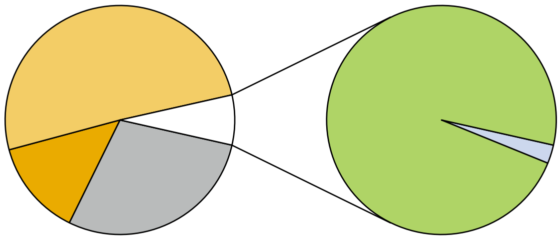


EU : rapeseed for biodiesel	2016
total land	410,477 kha
non-agricultural land	231,693 kha
meadows and pastures	63,706 kha
total land for rapeseed	6,085 kha
rapeseed for biofuel produced in EU, not for EU biofuel	1,137 kha
rapeseed for biofuel produced in EU, for EU biofuel	887 kha
rapeseed for EU biofuel produced outside EU	1,967 kha
rapeseed not for biofuel production in EU, not for EU biofuel	2,094 kha
other annual crops	108,993 kha

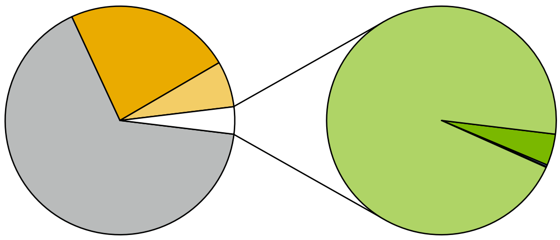
Total land — Land for rapeseed



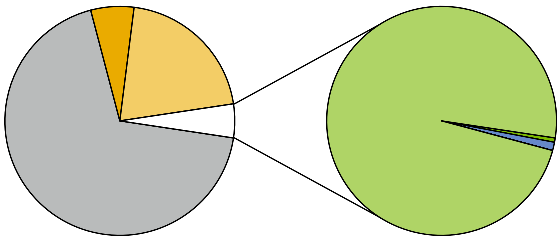
Ukraine : maize for bioethanol	**2016**
total land	57,929 kha
non-agricultural land	16,654 kha
meadows and pastures	7,841 kha
total land for maize	4,084 kha
maize for biofuel produced in Ukraine, not for EU biofuel	0 kha
maize for biofuel produced in Ukraine, for EU biofuel	0 kha
maize for EU biofuel produced outside Ukraine	107 kha
maize not for biofuel production in Ukraine, not for EU biofuel	3,976 kha
other annual crops	29,351 kha



Brazil : soybean for biodiesel	**2016**
total land	835,814 kha
non-agricultural land	553,225 kha
meadows and pastures	196,000 kha
total land for soybean	32,181 kha
soybean for biofuel produced in Brazil, not for EU biofuel	1,432 kha
soybean for biofuel produced in Brazil, for EU biofuel	84 kha
soybean for EU biofuel produced outside Brazil	31 kha
soybean not for biofuel production in Brazil, not for EU biofuel	30,634 kha
other annual crops	54,408 kha



Indonesia : palm oil for biodiesel	**2016**
total land	181,157 kha
non-agricultural land	124,157 kha
meadows and pastures	11,000 kha
total land for palm oil	8,630 kha
palm oil for biofuel produced in Indonesia, not for EU biofuel	53 kha
palm oil for biofuel produced in Indonesia, for EU biofuel	101 kha
palm oil for EU biofuel produced outside Indonesia	0 kha
palm oil not for biofuel production in Indonesia, not for EU biofue	8,476 kha
other annual crops	37,370 kha



Malaysia : palm oil for biodiesel	**2016**
total land	32,855 kha
non-agricultural land	25,016 kha
meadows and pastures	285 kha
total land for palm oil	4,859 kha
palm oil for biofuel produced in Malaysia, not for EU biofuel	0 kha
palm oil for biofuel produced in Malaysia, for EU biofuel	40 kha
palm oil for EU biofuel produced outside Malaysia	1 kha
palm oil not for biofuel production in Malaysia, not for EU biofue	4,818 kha
other annual crops	2,695 kha

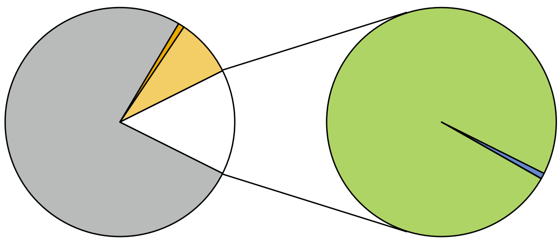


Figure 27. The share of crop production dedicated to EU biofuel production compared to other land uses, for major crop-country combinations.

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[112].

At the time of writing this report, 27 Member States submitted their 2016 Renewable Energy Progress Reports to the Commission. Of these, five Member States (Belgium[113], Cyprus, Estonia, Malta and Spain) 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, Germany, Bulgaria, Hungary, Luxembourg, the Netherlands, Poland, Sweden and Romania). 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, the Czech Republic, Finland, Italy, Lithuania, Portugal, Slovenia, Latvia and Greece) 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. Most Member States report data on land used for energy crops (all but Belgium, Cyprus, Estonia, Malta and Spain), although some only report the data for a certain land use type but not for others (e.g the Czech Republic, Finland, Hungary, Luxembourg, Portugal, Sweden and Slovenia). One Member State, Slovakia, reported the total crop land and showed the share of crops dedicated to bioenergy. In some of the reports, it is not clear whether the data represent total crop lands or only crop lands dedicated to bioenergy (e.g. this is the case for Austria, Bulgaria, Italy, Lithuania, Luxembourg, Portugal, Latvia and Romania). 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 (20 Mha) is compared to the calculated amount of land required to produce the total amount of biofuels consumed in the EU in 2016 (about 5 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

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

[113] Belgium provided a table for 2011-2012 in their recent Progress Report for which it is uncertain if they actually mean that period or made a mistake in the caption of the table.

the period 2015 – 2016 has been negative. While the land used for short rotation trees increased by 7.4%, the land used for other energy crops reduced significantly (about 21%) which occurred mainly in Bulgaria and Poland. The land used for the cultivation of common arable crops and oilseeds shows significant expansion in some Member States (Slovenia (94%), Portugal (40%), Austria (34%)) and reduction in others (the Netherlands (23%), the Czech Republic (16%), France (16%), Denmark (13%)) with an overall reduction of about 1% across the EU between 2015 and 2016. A significant increase can be seen in the period from 2011-2016, but this is to a large extent due to countries not reporting land use in the earlier years (e.g. Italy, Bulgaria). Yet, over 99% of the reported land in 2016 is land used for the cultivation of common arable crops and oilseeds. Again, note that in some of the reports, it is not clear whether the data represent 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 (31%), Italy (18%), Bulgaria (14%), Germany (12%) and France (6%) in 2016 (as a percentage of the total reported land by all Member States).

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

Member State	Common arable crops and oilseeds					
	2011	2012	2013	2014	2015	2016
Austria	67,500	67,300	77,500	71,500	38,100	51,400
Belgium	14,818	16,674	23,453	20,634	-	-
Bulgaria	-	-	-	-	2,886,137	2,864,916
Croatia	-	-	-	-	0	0
Cyprus	-	-	-	-	0	0
Czech Republic	189,620	172,426	159,745	164,463	159,797	134,551
Denmark	70,000	70,000	130,000	125,000	150,000	130,000
Estonia	-	-	-	-	-	-
Finland	n/a	n/a	n/a	n/a	0	0
France	1,107,199	1,230,073	-	1,162,799	1,375,450	1,158,600
Germany	2,051,000	2,147,400	1,979,700	2,211,300	2,431,800	2,396,700
Greece	88,975	67,389	78,460	80,491	102,545	77,483
Hungary	162,000	197,000	300,000	300,000	0	0
Ireland	297,000	315,000	320,599	318,042	311,787	299,453
Italy	-	-	-	-	3,665,076	3,677,980
Latvia	650,874	693,424	549,500	556,600	574,600	620,300
Lithuania	146,860	177,320	-	-	137,000	139,000
Luxembourg	569	581	531	591	932	848
Malta	-	-	-	-	-	-
Netherlands	4,000	4,000	800	800	3,000	2,300
Poland	n/a	n/a	601,370	553,975	2,612,581	2,560,021
Portugal	426	4,357	-	-	1,287	1,797
Romania	6,167	6,125	6,176,900	6,248,300	6,248,700	6,396,500
Slovakia	152,000	153,000	220,683	187,914	127,308	117,946
Slovenia	4,770	5,141	6,131	5,563	1,629	3,156
Spain	50,291	n/a	-	-	-	-
Sweden	n/a	n/a	n/a	n/a	0	0
UK	32,617	14,942	42,000	112,000	5,885	5,911
EU-28	5,096,686	5,342,152	10,667,372	12,119,972	20,833,613	20,638,862
2015 – 2016 (%)					**-0,9**	

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

	Short rotation trees						Other energy crops					
Member State	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Austria	1,300	1,500	1,500	1,500	1,240	1,221	1,137	1,214	1,179	1,173	1,075	1,078
Belgium	145	165	100	91	-	-	190	138	43	47	-	-
Bulgaria	-	-	1,584	1,595	0	0	n/a	n/a	-	-	6,821	3,286
Croatia	-	-	-	-	0	0	-	-	-	-	0	0
Cyprus	-	-	-	-	-	-	-	-	-	-	-	-
Czech Republic	771	1,292	1,589	2,086	2,838	2,869	n/a	n/a	n/a	n/a	0	0
Denmark	4,000	4,000	9,014	9,518	9,088	8,896	50	50	85	80	78	66
Estonia	-	-	-	-	-	-	-	-	-	-	-	-
Finland	40	36	42	24	23	26	10,444	14,949	8,549	7,501	5,776	5,452
France	4,466	4,508	4,062	5,539	0	0	n/a	n/a	-	-	0	0
Germany	4,000	4,900	6,000	6,000	6,600	6,600	3,000	2,000	3,200	4,900	4,900	5,400
Greece	-	-	-	-	0	0	-	-	-	-	0	72
Hungary	3,000	n/a	n/a	n/a	4,082	4,104	n/a	n/a	n/a	n/a	0	0
Ireland	689	839	914	1,033	1,052	1,046	2,413	2,349	2,055	1,612	1,285	1,100
Italy	6,000	6,000	5,000	5,000	0	0	n/a	n/a	-	-	0	0
Latvia	209	321	6,628	-	0	0	1,155	884	-	-	0	0
Lithuania	1,500	2,000	-	-	3,436	4,063	n/a	n/a	-	-	0	0
Luxembourg	n/a	n/a	n/a	n/a	0	0	145	84	187	92	215	211
Malta	-	-	-	-	-	-	-	-	-	-	-	-
Netherlands	13	6	7	20	33	13	91	124	191	190	280	245
Poland	7,619	10,344	11,486	13,499	276	804	n/a	n/a	-	-	18,406	10,000
Portugal	n/a	n/a	-	-	0	0	n/a	n/a	-	-	0	0
Romania	n/a	n/a	n/a	n/a	300	3,200	0	0	0	0	0	1,200
Slovakia	n/a	n/a	590	650	0	0	n/a	n/a	-	-	0	0
Slovenia	n/a	n/a	-	-	0	0	n/a	n/a	-	-	0	0
Spain	n/a	n/a	-	-	-	-	n/a	n/a	-	-	-	-
Sweden	12,064	11,861	11,825	11,637	11,102	10,193	828	912	906	646	661	669
UK	2,720	2,551	3,000	3,000	10	10	7,517	8,075	7,000	7,000	11,046	11,222
EU-28	48,536	50,323	63,341	61,192	40,080	43,045	26,970	30,779	23,395	23,241	50,543	40,001
2015 – 2016 (%)					**+7,4**						**-20,9**	

Historical developments of land use of crops commonly used for biofuel production

Figure 28 shows the historical development of cropland globally used for food and feed crops which are commonly used as feedstock for the production of biofuels, namely wheat, sunflower, sugar cane, sugar beet, soybeans, rapeseed, oil palm and maize.

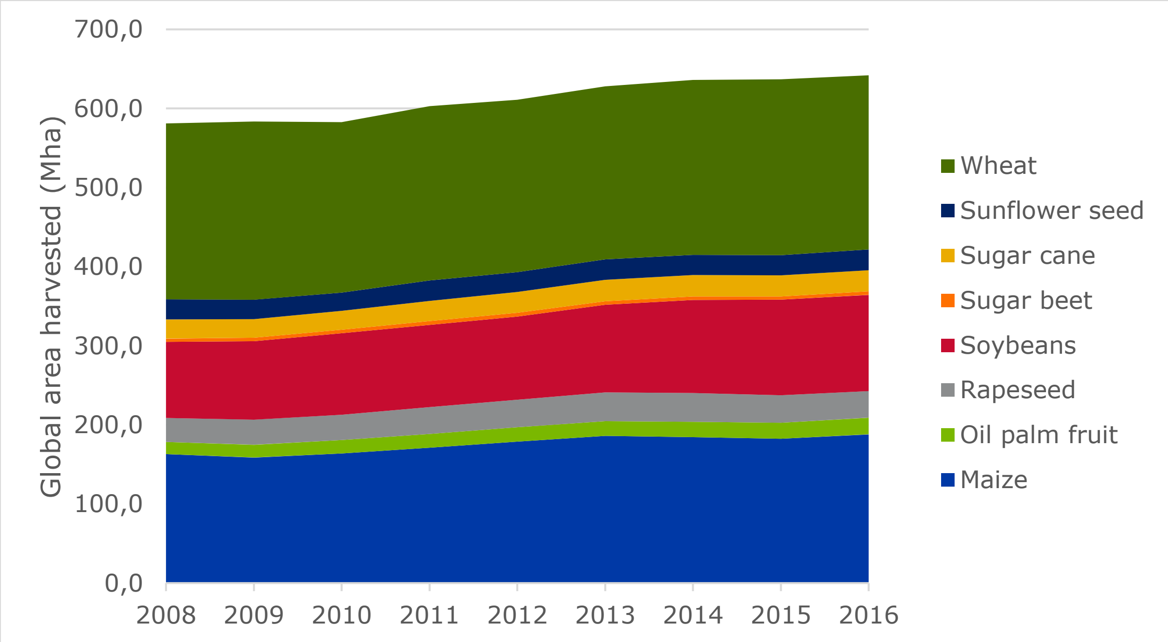


Figure 28. Global historical development of land used for production of most common food and feed crops [FAOstat].

The figure shows that since 2008, global cropland used for cultivation of food and feed crops which are also (but not uniquely) used as feedstock for production of biofuels has steadily increased. In 2016 the area used for these crops globally was 10% larger than in 2008 reaching more than 640 Mha in 2016. This is more than 100 times the acreage calculated for biofuels feedstock at the start of this section, which confirms the view that biofuels play at present still a small role in the land use of these crops. The largest increase in cropland for these crops occurred in the period 2011-2013, with a relative low growth in the last two years (resp. 0.1% in 2015 and 0.8% in 2016). Almost all crops show an increase in harvested area, with oil palm and soybean being the largest contributors in terms of growth compared to their 2008 area harvested (37% and 26% respectively). Wheat is the only crop for which the harvested area declined in the period 2008-2016 (by 1%). Rapeseed has increased overall in terms of area harvested in the period 2008-2016, but the peak in the area harvested was in 2013 and 2014. Since then the area harvested has decreased (by 8% in 2016 compared to 2014).

The palm oil area harvested in the period 2008-2016 (see Figure 29) mainly increased in Indonesia. The peak in the rate of annual increase in Indonesia was in 2014, after which annual increases slowed down (from 15% in 2014 to 6% in 2015 and 8% in 2016). Malaysia experienced a steady expansion in the area harvested of around 3% per year between 2008-2016.

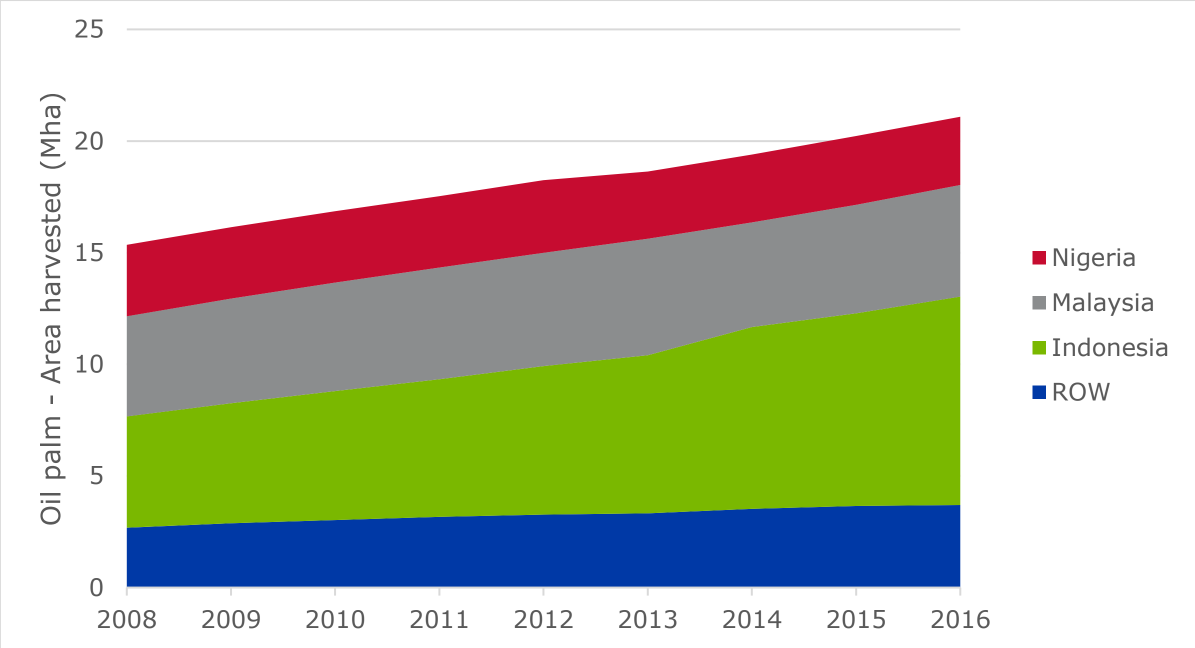


Figure 29. Global area of palm oil harvested split in main producing regions and ROW (rest of world) [FAOstat].

The soybean area harvested in the period 2008-2016 (see Figure 30) mainly expanded in Brazil. The peak in expansion between 2013 and 2014 in the rest of the world is partly explained by area expansion in the USA, Paraguay, Russia and Ukraine.

For maize, large producers such as China and India show an above average (more than 25%) increase in area harvested over the period 2008-2016. China, however, represents in quantitative terms by far the largest expansion, representing 9 Mha of the total global expansion of 15 Mha. The USA follows with an area expansion of 3 Mha. For rapeseed specifically, Australia and Canada show a large expansion in the area harvested in the period 2008-2016, not only in percentage (86% and 23% respectively) but also in quantitative amount (1.1 Mha and 1.5 Mha respectively). [114]

[114] All data from FAOstat.

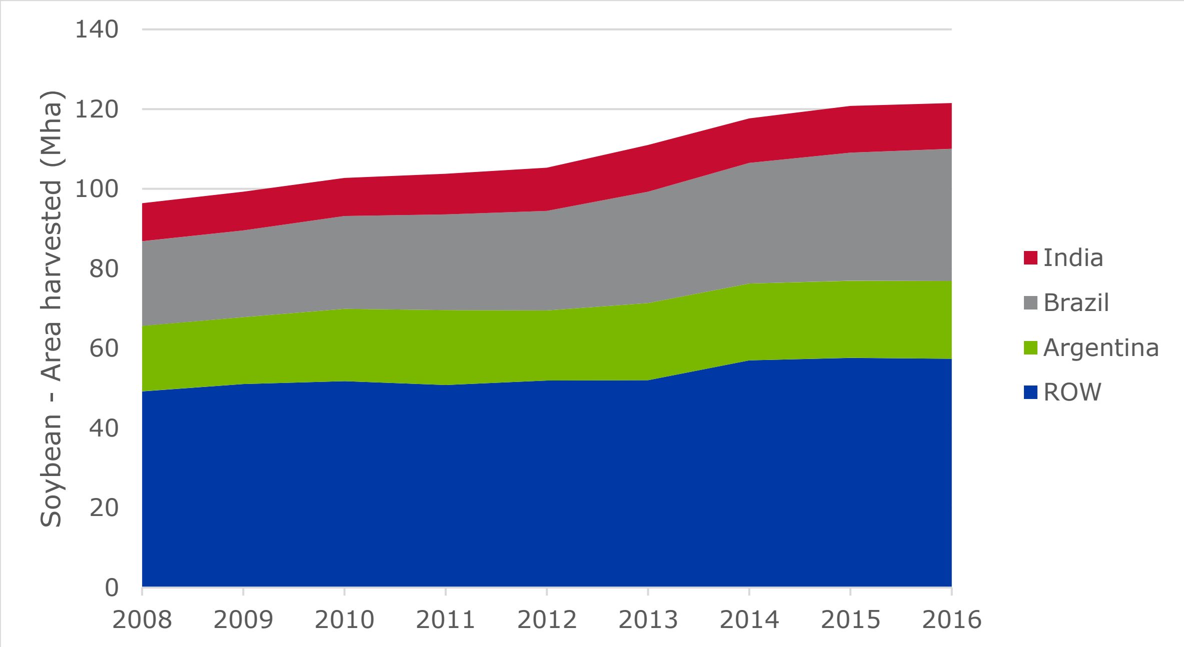


Figure 30. Global area of soybean harvested split in main producing regions and ROW (rest of world) [FAOstat].

It is not possible, based on this information, to directly link these developments to the EU biofuel consumption, since these crops are used for a range of purposes (e.g. food and feed). What it does show is that especially in Indonesia and Brazil there is still a considerable/high risk of land expansion.

5.3 Greenhouse gas emission savings

The assessment of greenhouse gas performance related to renewable energy in transport is limited to 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[115]. Second, the total savings are calculated from combining insights into the biofuels consumed with typical savings. A comparison of the two results is given at the end of this section with possible clarifications for the differences.

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, 27 Member States submitted their Renewable Energy Progress Reports. Of these, one Member State did not report on the greenhouse gas emission savings (Belgium), and one other Member State (Estonia) only reported on greenhouse gas emissions savings in the electricity sector and not on savings in the transport sector. 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, since biofuels account for 88% of the renewables used in transport (without the multipliers of the total

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

renewable energy in transport), it can be expected that the emission savings largely result from the use of biofuels. In some Member States[116] 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 33.2 Mtonne CO_2eq in 2016, which is a marginal decrease (-1.7%) in savings as compared to 2015. This is unexpected as the share of renewable energy in the EU transport sector increased over the period of 2015 – 2016 (it was 7.13% in 2016 and 6.58% in 2015).[117] As mentioned, the emission savings in the transport sector are expected to be largely due to the use of biofuels. The share of biofuels in EU transport increased by about 7% between 2015 and 2016. It is possible that the additional biofuels came from biofuels with higher emission factors,[118] thus resulting in lower emission savings, as compared to the fossil fuel comparator. Significantly lower emission savings were reported especially in Austria, Finland, Latvia, Poland and Slovenia in 2016, as compared to 2015 (Table 14), which can be attributed to the reduction in their renewable energy share in transport (see Figure 9). The only country showing a substantial increase (~40%) in emission savings is Sweden, having the highest renewable energy share in its transport of all Member States.

[116] Countries with high share of renewable electricity in transport such as Latvia (31%), Austria (27%), Italy (24%) and Slovenia (21%); source: SHARES database

[117] SHARES dataset

[118] Biofuels emission factors vary per type and strongly depends on parameters such as the origin of feedstock, transport mode and transport distance

Table 14. Greenhouse gas emission savings from the use of renewable energy in transport (ktonne CO_2eq) as reported in Member State Progress Reports.

	GHG saving (ktCO_2eq)	
Member States	**2015**	**2016**
Austria	2,100	1,700
Belgium	n/a	n/a
Bulgaria	202	228
Croatia	n/a	n/a
Cyprus	28	29
Czech Republic	789	732
Denmark	700	700
Estonia	n/a	n/a
Finland	980	360
France	5,930	6,050
Germany	6,300	6,900
Greece	351	291
Hungary	0.29	0.31
Ireland	264	238
Italy	2,400	2,700
Latvia	45	25
Lithuania	0.29	0.23
Luxembourg	257	275
Malta	12	16
Netherlands	780	638
Poland	2,976	1,878
Portugal	1,057	859
Romania	936	308
Slovakia	248	255
Slovenia	90	56
Spain	2,069	2,274
Sweden	2,800	3,900
UK	2,463	2,784
EU	**33,777**	**33,197**

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 on 2016. 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. For instance, European feedstocks for biofuels that increased in the 2000-2010 period have caused between 0 and 7 g/MJ of ILUC,[119] compared to the provisional mean ILUC values for the 2010-2020 period ranging from 12-13 g/MJ (cereals and sugars) to 55 g/MJ (oil crops) in the ILUC Directive. When the 2016 crop feedstock volumes are

[119] Biofuels feedstock that was produced on set-aside land did not lead to ILUC as it did not displace food crops (0 g/MJ ILUC). Furthermore, biofuels feedstock that was produced on existing crop land avoided land abandonment (of the same land, or elsewhere in the system), this according to GLOBIOM has a maximum impact of 7 g/MJ. Note that about 5 million hectares of agricultural land was abandoned in the EU in the 2000s, while the total EU land for rapeseed biodiesel is about 3 million hectares. Finally, rapeseed yields in the EU strongly increased from 2.75 tonne per hectare in 2002 to 3.61 tonne per hectare in 2015. Comparing the increase of rapeseed oil methyl ester (RME) over this period (about 5 Mtonne) with the increase of EU produced rapeseed (13 Mtonne), makes clear that RME was probably the only driver for the rapeseed cultivation increase. It can be concluded, that about 45% of the additional RME production was accommodated by yield increase, while the remainder was achieved on "additional" land [Oil World statistics summarized in Nazlin 2017, Competitiveness of the rapeseed industry in the European Union, Oil Palm Industry Economic Journal 17(1): 32-50]. Additional biofuels feedstock that is produced through increased yields, is regarded low ILUC risk.

multiplied with the corresponding mean ILUC values from the ILUC Directive, this suggests that the emission savings from renewable energy in transport is reduced to 11.8 Mtonne of CO_2 savings (with a range from 7.4 Mtonne to 20.4 Mtonne of CO_2 savings). As explained above however, this an underestimation of savings, caused by an overestimation of ILUC.

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 typical greenhouse gas emissions for biofuels supply chains as set in the Renewable Energy Directive, see Table 15. 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. Also, it does not recognise that biofuels placed on the EU market may have a better greenhouse gas performance than what is "typically" assumed in the Directive.

A total greenhouse gas emission savings of 28.4 Mtonne CO_2eq (60% savings) was achieved by using 16,531 ktonne of biofuels as compared to the situation where only fossil fuels would have been used. This is an increase compared to the estimated 27.3 Mtonne CO_2eq related to the 2012 EU biofuels consumption (same methodology, Ecofys 2014). The emission savings have increased despite a decrease in biofuels consumption since then (17,592 vs 16,531 ktonne in 2012 and 2016, respectively). This increase is a result of using more Annex IX biofuels[120] and improvement in greenhouse gas performance of biofuels across the value chain.

Table 15. Overview of total greenhouse gas savings related to EU biofuel consumption in 2016. The typical savings are an aggregate result from combining the estimated feedstock shares with typical values reported in the Renewable Energy Directive.

Fuel	Total consumption 2016 (ktonne)	Total consumption 2016 (TJ)	Typical GHG emission (g CO_2eq/MJ fuel)	GHG savings [1] (Mtonne CO_{2eq})
Bioethanol	4,142	109,358	33.7	5.5
Biodiesel	12,388	454,587	33.3	23.0
Total biofuels	16,531	563,945	33.4	28.4

[1] The fossil fuel comparator is 83.8 g CO_2eq/MJ fuel according to Directive 2009/28/EC.

The explanations for the difference between the 33.2 Mtonne of CO_2 savings from renewable energy in transport, as reported by the Member States, and the 28.4 Mtonne of CO_2 savings from the use of biofuels in transport, estimated from the crop-fuel combinations are as follows:

- The estimations on the basis of crop-fuel combinations consider only liquid biofuels and exclude gaseous biofuels and renewable electricity in transport.
- Member States may have used more detailed input on the actual biofuels used (e.g. reported performance can be more accurate than the typical values as applied in the estimations).

[120] Consumption of sustainable biofuels from Annex IX feedstocks was 603.7 ktoe in 2012 and increased to 3842 ktoe in 2016 [SHARES dataset]

5.4 ILUC science update

CENER provides an overview of all literature available in the field of ILUC up until the end of 2016 and arrives at two main conclusions:[121]

- ILUC factors identified in the literature vary significantly across biofuel pathways, studies, or even within studies. Studies that have investigated parametric uncertainty conclude that parametric uncertainty has a significant effect on the outcomes. As a consequence of all the uncertainties in the components of ILUC emissions, it is very difficult to narrow them down.
- Low ILUC-risk feedstocks, especially residues from forestry or agriculture as well as dedicated energy crops may be relatively promising, but the sustainable supply potential for the use of these residues may be limited. The use of these residues can impact other uses of these residues or can cause indirect carbon loss in agricultural or forest land when these residues are removed.

In the past year only limited additional scientific studies were published on the topic, with the following conclusions:[122]

- One study presented case studies of sugarcane expansion in the Brazilian Cerrado and assessed ILUC risks at the farm level. It assessed ILUC risks from a farm level perspective rather than from a regional or global perspective. The study reviewed socio-economic, policy and farm level factors and the extent they influence farmers' decisions to expand activities onto other land. They for instance estimated that in the case whereby farmers were risk avoiders or where the farm provided a higher share of the household income, then the risk of ILUC on the farm significantly increased. Farmers would then rather move activities to lower yielding land rather than abandoning these activities.[123] The study does not make clear how such farm level factors influencing ILUC links to regional or global ILUC.
- Another study examined the economic effects and additional carbon savings from including an ILUC factor in implementing a Low Carbon Fuel Standard. In their analysis Khanna et al showed that the inclusion of an ILUC factor in a national Low Carbon Fuel Standard led to additional abatement of cumulative emissions over the period 2007–2027 by 1.3 to 2.6%, equalling 0.6–1.1 billion tonne CO_2eq compared to those without an ILUC factor, depending on the ILUC factors utilized.[124]

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[121] CENER identified 1,248 studies in the period 2012-2016 that mentioned ILUC, which after applying several selection criteria gave 105 eligible studies providing quantitative information, 166 providing non-quantitative information, as well as 31 pre-2012 landmark studies [CENER 2017, Study report on reporting requirements on biofuels and bioliquids stemming from the directive (EU) 2015/1513, For European Commission].

[122] We have done a literature search and connected to internal as well as external (Hugo Valin and David Laborde) experts in the field of ILUC to identify studies and sources.

[123] [Bergtold 2017, Indirect land use change from ethanol production: the case of sugarcane expansion at the farm level on the Brazilian Cerrado, Journal of Land use sciences 12(6), and Granco et al. 2018, Farmers' acreage responses to the expansion of the sugarcane ethanol industry: The case of Goiás and Mato Grosso Do Sul, Brazil, Land Allocation for Biomass Crops, pages 103-123].

[124] [Khanna M. et al. 2017, The social inefficiency of regulating indirect land use change due to biofuels. Nature Communications 8].

in Europe, recent research is focusing less on quantification of ILUC, and more on ILUC mitigation or the potential of low ILUC biofuels. Examples of recent publications are:

- A report with detailed methodologies for the identification and certification of low ILUC risk biofuels focusing on opportunities related to yield increase (e.g. sequential cropping) and the potential of unused land.[125]
- A study on the rapeseed biodiesel potential and the greenhouse gas emission savings of four measures to make surplus land available in 2020 by using a case study in Eastern Romania. Four scenarios varying in assumptions on productivity and sustainability in the agricultural sector show the variation in the potential of these measures. The study shows that low-ILUC-risk rapeseed biodiesel has a potential of 3-64 PJ, 1-28% of the projected Romanian transport diesel consumption. Depending on the scenario applied, surplus land of 2,000-18,000 km^2 could become available (6-43% of the agricultural land in the region analysed). Average greenhouse gas emissions of the ILUC mitigation measures range from –11 to 22 g CO_{2e}/MJ, which means ILUC mitigation is possible, provided that the entire agricultural sector is sustainably intensified (beyond biofuels alone).
- A study on maize production in Hungary assessed scenarios in which agricultural land demand is reduced by 3500-16000 km^2 in 2020 compared to the current situation (6-29% of the agricultural area) through ILUC risk mitigation. The ILUC mitigation measures included in the scenarios analysed are: 1) above baseline yield increase, 2) improved chain integration (e.g. better use of co-products), 3) reducing losses in the supply chain and 4) using under-utilised lands. This surplus land could then be used to provide 22-138 PJ of ethanol.[126]
- Another study reviewed how the EU policies on ILUC can support the development of biochar in arid lands within Europe. It concludes that the use of biochar and compost solutions can prevent abandonment of agricultural land, specifically in areas which are at risk of marginalization (‘positive land use change’). With about 8.5 Mha of land at risk of marginalization within the EU Mediterranean area, 156 Million tonne CO_2 could be sequestered.[127]

Besides scientific research, there is also increasing attention of market parties (e.g. biofuel producers) to actively engage in developing low ILUC biofuels and assessing their market potential.

5.5 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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[125] [Ecofys 2016 - Peters et al, Methodologies for the identification and certification of Low ILUC risk biofuels.]

[126] [M.L.J. Brinkman et al. 2017, Low-ILUC-risk ethanol from Hungarian maize, Biomass and Bioenergy 99: 57-68.]

[127] [Chiaramonti and Panoutsou 2018, Low-ILUC biofuel production in marginal areas: can existing EU Policies support biochar deployment in EU MED arid lands under desertification?, Chemical Engineering Transactions 65.]

Member States Progress Reports[128]

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 a voluntary schemes or national system to provide proof that they originate from sustainable production. Detailed information per Member State is provided in Table 16.

Table 16. Overview of answers provided in Member State Progress Reports to 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
Austria	Austria reports that all biofuels use a voluntary scheme or national system to provide proof that they originate from ‘sustainable production’. Austria has developed a national system for all biofuels produced within the country. The most widely applied voluntary scheme (for biodiesel as well as bioethanol) is ISCC. 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 report only states that ’the production of biofuels is not known to have had any adverse effect on biodiversity, water and soil quality’. 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, no negative impacts on biodiversity were observed related to the production of biofuels and other bioliquids.
Croatia	The Croatian report was not available at the time of analysis.
Cyprus	Cyprus states that in 2015 and 2016 there was no significant domestic production and therefore that there are no impacts on biodiversity, water resources, water quality and soil quality in Cyprus.
Czech Republic	The Czech reports 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 annually monitored and have not changed considerably over the past years. They state that this indicates that the impact of biomass production for energy use on agricultural land was neutral during the monitoring period. 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. No other information is provided.

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

Member State	Information reported on environmental impacts related to biofuel/bioliquid production
Estonia	The Estonian report only states that 'no biofuels are produced in Estonia, and as a result there are no impacts, and 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 report only states that 'the impact of biofuel production on 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 this 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. In the annex of the Progress Report, Germany provided additional details on origin of feedstock used for biofuels and on voluntary schemes used for compliance demonstration.
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 in the period 2014-2016 and conclude that the production of raw materials for biofuels and liquid fuels within Hungary in the period 2014-2016 was not so high that it would place an additional burden on environmental resources.
Ireland	Ireland indicates that all feedstock for domestic biofuel production have been wastes and residues (UCO and tallow). 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 report states that land use for energy crop production is limited, and therefore that their production does not have a significant impact on the rural ecosystem. 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 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 state that they have not evaluated these impacts in 2015/2016. No further information is provided.
Luxembourg	Luxembourg indicates that compared to the third progress report there is no change to information on the expected impacts. No other information is provided.
Malta	Malta indicates that local biofuel production mainly uses cooking oil waste streams. They conclude that there is minimal, if any, negative impact on biodiversity, water resources, water quality and soil quality. They add that the sole local manufacturer of biofuels has to abide by Integrated Pollution Prevention and Control regulations.

Member State	Information reported on environmental impacts related to biofuel/bioliquid production
	Finally, they state that this local production is considered as having a positive impact on the environment as it reuses waste.
Netherlands	The Dutch report states that hardly any biofuels are made from feedstock grown in the Netherlands and thus that environmental impacts related to production within the country are negligible. No other information is provided.
Poland	The Polish 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 and that the stipulated sustainability criteria are being met, there does not appear to be any impact on biodiversity, water resources or soil quality at national level. No other information is provided.
Romania	The Romanian 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 in 2015 or 2016.
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 2016 in Slovakia did not increase significantly compared to the previous period.
Slovenia	The Slovenian 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 report indicates that no new agricultural land has been used for the production of biofuels, therefore impacts on biodiversity and soil are expected to the same as normal/food crop production. Also, the report indicates that impacts on water are not relevant for the Swedish case, since there is no shortage of water in Sweden. Regarding soil and water quality, the report provides results from a life cycle assessment to assess impacts on acidification and eutrophication. The report does not provide concrete conclusions on the possible impact related to acidification and eutrophication.
UK	The UK 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.

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

Risks of local environmental impacts have been assessed for the main crop/country combinations that are representative of biofuel consumption in the EU in 2016. For each of the impact categories (soil, water, air and biodiversity), a brief assessment was done of typical environmental risks associated with the feedstock in a specific country. However, the impacts are typically site-specific, while there is no site-specific information for the feedstock of the biofuels that find their way in the EU market. This means that it is not possible to conclude if these risks are present in the specific supply chains delivering feedstock used for the production of biofuels consumed in the EU. Moreover, crops used as EU biofuel feedstock have to adhere to the RED sustainability criteria which should eliminate most risks of unsustainable practices in biofuel production consumed in the EU. This implies that the analysis cannot be used to conclude if risks lead to real impacts. The detailed exploration of potential local environmental risks related to the main feedstocks and main regions of origin, can be found in Appendix C.

5.6 Relevant international conventions

The Renewable Energy Directive requires insight into whether countries that are 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 17. 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)]
Australia	√	√	√	√	√	√		√	-	R
Brazil	√		√	√	√	√	√	√	ACS	R
Indonesia	√	√	√	√	√	√	√	√	R	ACS
Malaysia	√		√	√	√		√	√	R	ACS
Canada	√	√	√	√	√	√	√	√	-	R
Russia	√	√	√	√	√	√	√	√	-	C
Ukraine	√	√	√	√	√	√	√	√	ACS	ACS
USA					√			√	-	R
EU 28	√	√	√	√	√	√	√	√	See Table 18	

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 18. 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 17 shows that ILO conventions have been ratified in many of the countries important for providing the EU biofuels feedstock. Only the USA has not ratified most of the ILO conventions. Also, Malaysia and Brazil have not ratified some of them. Compared to earlier assessment in 2012, the progress in these countries is limited. In particular, in the USA there have been no changes. 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. Canada implemented the ILO conventions 98 and 138 between 2014 and 2018.

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. In most countries where the ILO commented on the implementation or enforcement of ILO conventions this concerns mainly ILO 100 and 111, on topics like equal remuneration for men and women, equal job opportunities, discrimination against women and minorities etc. Most of the comments indicate specific inclusion of aspects of the convention, or measures to encourage or promote equal opportunities or remuneration. The ILO requested additional information on enforcement, statistics or example programmes. The ILO provided comments on ILO convention 87 and 98 for some countries regarding the right to collective bargaining and the functioning of trade unions. Most of them concern specific sectors which are not always relevant to biofuel production (e.g. civil service or shipping employees).

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) publishes a list (published 2018) of goods where child or forced labour sometimes occurs in their production. Examples on that list are Brazilian sugar cane (child labour and forced labour), 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. Criteria in the Voluntary Schemes should avoid these impacts in biofuels supply chains.

The overall trend (inside and outside the EU) is that equal remuneration for women/men/minority groups is the least enforced convention over the various countries. Some countries are urged to ensure appropriate action against forced labour of migrants, specific social groups and people trafficking. Only for the USA (hazardous work in agriculture from 16 years of age) agriculture is mentioned as a specific sector of attention for ILO conventions they have ratified.

Table 17 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. Canada, Russia and the USA have neither ratified nor accepted the convention. Table 18 shows that most Member States have accepted or ratified the CPB and CITES conventions.

There are some concerns with enforcement of conventions, either by the ILO or by civil society organisations. The ILO mostly has concerns on the complete transposition of aspects like equal remuneration and discrimination. The only comments they make in specific relation to agriculture concern the USA (about hazardous situations for children) and Brazil (worst forms of child labour). Civil society organisations often report concerns on actual enforcement regarding forced labour. Child labour in palm oil plantations (Malaysia and Indonesia) and sugar cane plantations (Brazil) are mentioned as cases of concern.

Due to the relatively slow ratification of ILO conventions, few changes in the past period (2014-2018) 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.

6 Economic, and social impacts related to biofuels

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.

There are several studies published on the topic of biofuels and food prices. However, the majority of these studies focuses on a few years mostly around the food crises of 2006-2008 and none cover developments after 2012. Limited studies deliver strong analysis and conclusions on the topic of food prices and biofuels over a longer time period. Although several studies indicate a relationship between biofuels and food prices, all indicate that there are many other factors and the role of biofuels remains relatively limited.

It is estimated that the production of biofuels and their feedstock employed over 200,000 people in the EU in 2016, compared to 180,000 in 2015. Most of the employment is in Poland, France, Romania and Germany. In Indonesia, Malaysia and Brazil much more jobs relate to EU biofuels consumption.

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 5.6, together with conventions on biodiversity.

6.1 Food prices and affordability

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

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 must lead to crop shortages and increasing food commodity prices. Figure 31 shows a composite food price index and annual biofuels production volumes. The increasingly faster 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 goes against 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 slows down in 2010-2011, while another price spike in crop prices occurs in 2011. In the last five years a more moderate increase in biofuel production is observed, alongside a slight decline, followed by a stabilisation, in crop prices. There has been no apparent correlation between crop prices and biofuel production since 2008.

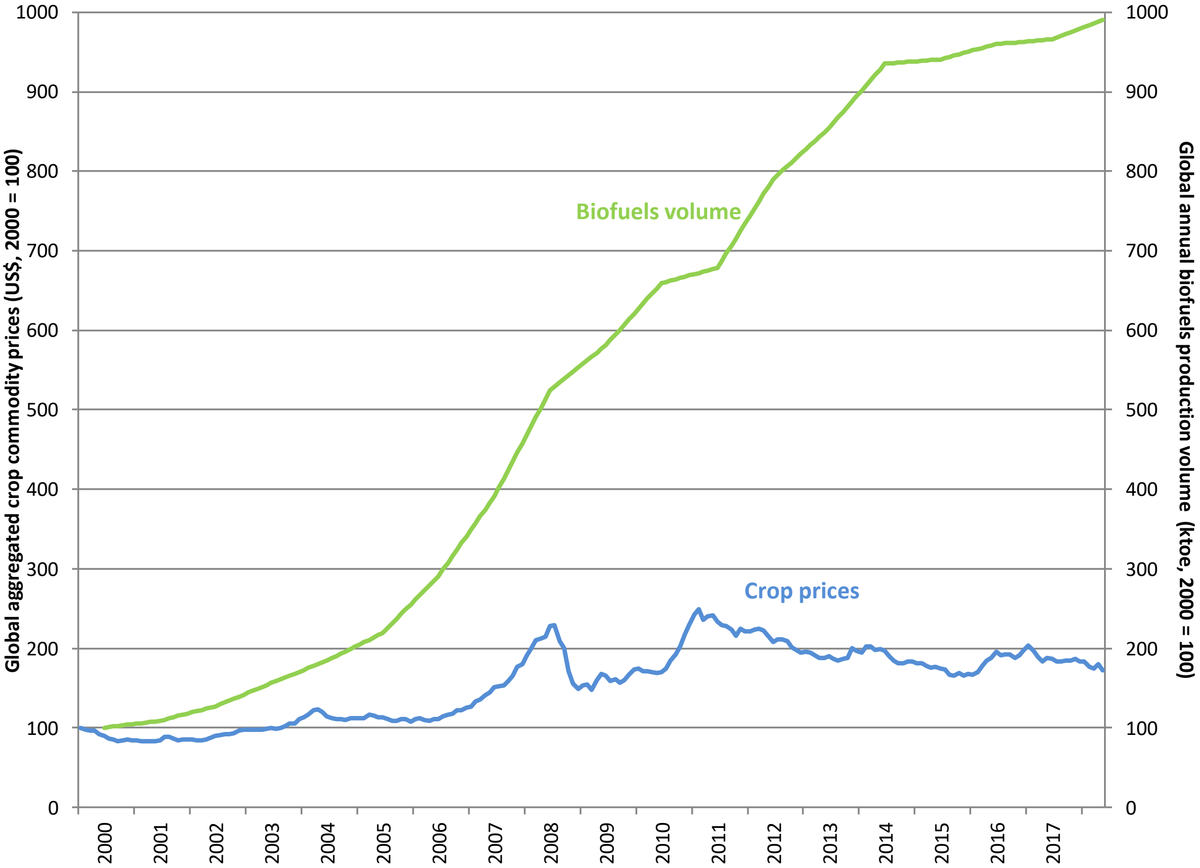

Figure 31. Global crop commodity prices and the aggregated price of all commodities,[129] versus global biofuels production volume,[130] both normalised. The food price index is derived by averaging all food/crop commodities in the World Bank monitor on commodity prices.

Several studies have concluded that biofuels did not cause the price spikes, but that their impact is likely more nuanced.[131] A strong demand for crop-based biofuels should have an impact on the price of feedstock but this leads only to small variations on global agricultural commodity prices, and thus these impacts cannot be observed.

[129] World Bank, 2013, World DataBank - Global Economic Monitor (GEM) Commodities, accessed August 2018.

[130] Biofuels production volumes is calculated as the sum of biodiesel and bioethanol production in the EU (according to Eurostat) and the rest of the world (according to US EIA Energy Information Administration and FO Licht statistics).

[131] For an overview and discussion of studies, see [Ecofys 2013, Biofuels and food security].

At present, few, if any, studies exist on the impacts during the 2015-2016 focus years of the current study. Cerulogy gives a thorough overview of studies published until 2017, but none cover impacts after 2012.[132]

For the future, the studies cited by Cerulogy expect the strongest biofuel consumption growth in developing countries. Some argue that second generation biofuels can even help food security.[133] The impacts depend on whether the feedstock compete with traditional crops or is a co-product in their production. Biofuel from crop residues, such as corn stover and wheat straw, can lead to more land in these uses, potentially reducing food and feed prices.

Food prices in Member State Progress Reports

In the Member States Progress Reports[134] any changes in commodity prices associated with increased use of biomass within their Member State has 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, 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, Sweden, Slovenia, Latvia, Greece, Slovakia) 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. France's Progress Report included a review of the international literature (e.g. HLPE 2013[135]) on this topic, concluding that it is very difficult to split influencing factors on food price developments.

Germany presented an extensive analysis of a range of different biomass feedstock types (e.g. wood chips, logs, vegetable oils, biogas substrates). In their analysis of wood-like biomass prices for several products, an increase in prices as well as demand can be observed. A strong influence from heating oil and oil prices is also seen from the trends as analysed. For vegetable oils, Germany indicates that their prices are largely determined by the world market.

6.2 Labour and (local) employment

Figure 32 provides an overview of the estimated total employment[136] related to the EU biofuel consumption 2016 in the main countries of supply.

132 [Malins 2017. Thought for food - A review of the interaction between biofuel consumption. and food markets. Cerulogy, London].

133 [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.

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

135 [Biofuels and food security, Report of the High-Level Panel of Experts on Food Security and Nutrition, HLPE, 2013].

136 Direct employment refers to the employment in the sectors directly included in the supply chain of biofuels. It does not look at employment in sectors supplying or servicing the sectors within the supply chain (that would be indirect employment). Gross employment refers to the fact that any jobs which have become redundant in other sectors due to the employment created within these sectors has not been deducted. Thus, in case of job loss in the fossil fuel sector, this has not been deducted from the jobs created in the biofuel industry.

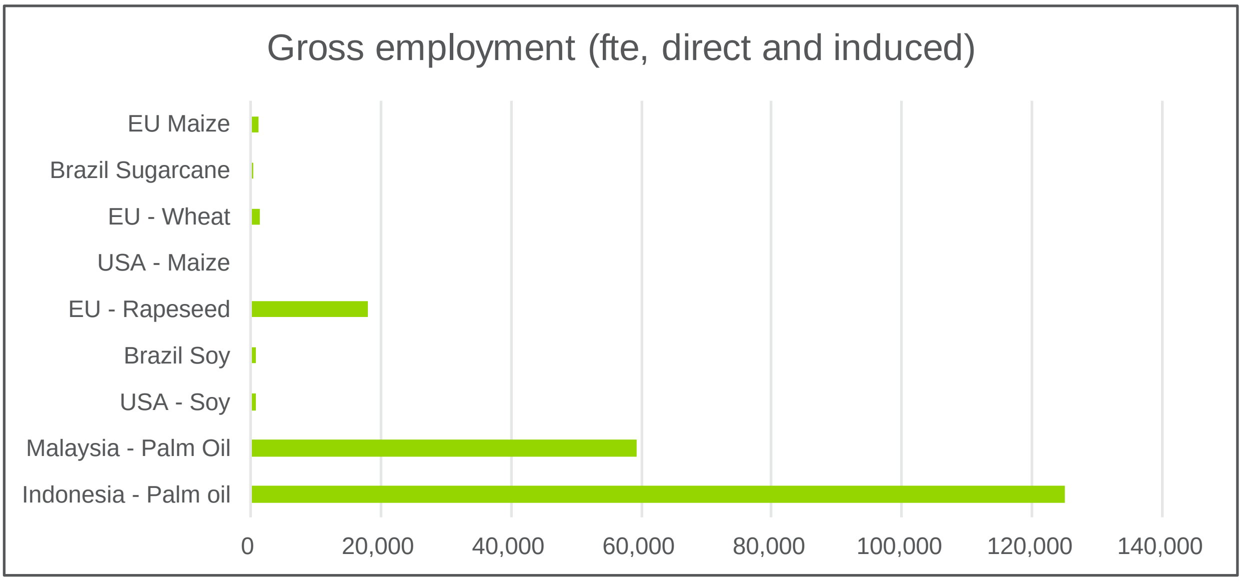

Figure 32. Estimated direct total employment (direct and indirect) related to EU biofuel consumption 2016, in full time equivalents. (Chum et al, 2012) (APEC, 2010).

It can be seen from Figure 32 that the largest share of employment arising from EU biofuel consumption is located outside of the EU, specifically in Indonesia and Malaysia.

EurObserv'ER[137] indicates a total of 205,100 direct and indirect jobs in the EU related to the biofuel sector in 2016, an increase compared to 2015 (178,200). Most of this employment is in Poland (17%), France (16%), Romania (12%) and Germany (11%).

Table 19 provides insights into the background data used to estimate the total direct gross employment. For crops like palm oil and sugar cane the largest part of the employment is created in the agricultural part of the value chain. For rapeseed, soy, wheat and maize, that part represents less jobs due to a higher degree of mechanisation and therefore only less than half of the employment is created in the agricultural part of the value chain.

[137] Source: EurObserv'ER website: https://www.eurobserv-er.org/category/all-annual-overview-barometers/

Table 19. Overview of employment per PJ for the main country/crop combinations (Chum et al, 2012) (APEC, 2010).

Country	Crop	Employment (FTE/PJ)[138]
Indonesia	Palm oil	2,000
Malaysia	Palm oil	2,000
USA	Soy	100
Brazil	Soy	100
EU	Rapeseed	100
USA	Maize	51
EU	Wheat	51
Brazil	Sugarcane	1,848
EU	Maize	51

Jobs in the agricultural part of the value chain especially are usually low income and low schooling jobs. In many countries and sectors, mechanisation is seen as an alternative, reducing environmental and health concerns in agricultural practices. However, this also reduces the amount of jobs available in the sector, giving a precarious balance between low quality jobs and unemployment.

6.3 Impact on other biomass using sectors

A wide range of different biomass feedstocks can be used for biofuel and bioenergy production. 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 lead to potential negative impacts on the current biomass using sectors.

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 used cooking oil and animal fats (partially) are included in Part B of Annex IX.

Table 20. Biomass feedstock types and their possible uses.

Type of feedstock	Existing use	Raw material
Woody residues[139]	Left in forest	Bark, branches (including tops), leaves (and needles), sawdust from forestry operations
	Pulp & paper production, panel board production	Branches (including tops), sawdust and cutter shavings from sawmills
	Mulch	Bark, branches (including tops),
	Animal bedding	Branches (including tops) – as fine wood chip, sawdust and cutter shavings from sawmills

[138] Chum et al 2011, APEC 2010

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

Type of feedstock	Existing use	Raw material
	Landscaping, playground surfacing	Bark, branches (including tops)
	Wood pellet or briquette production	Branches (including tops), sawdust and cutter shavings from sawmills
Straw	Incorporation	Any straw
	Animal bedding	Cereal straw
	Animal feed	Cereal straw - barley and oat straw are preferred
	Mushroom production	Wheat straw preferred – can also be barley straw
	Frost protection	Cereal straw
	Strawberry production	Cereal straw – barley straw is preferred
	Building materials (straw bales, straw panels, straw board)	Wheat straw
	Thatching	Wheat straw
	Paper and pulp	Cereal straw
Used cooking oil[140]	Animal feed (restricted in the EU and some third countries)	Used cooking oil
	Oleochemicals (detergents, soap, cosmetics etc.)	Used cooking oil
Animal fats (tallow)	Animal feed	Category 3 animal fats
	Process fuel in the rendering facility for process heat and power	Category 1
	Oleochemicals (detergents, soap, cosmetics etc.)	Category 3 animal fats
	Pet food	Category 3 animal fats
Crude tall oil	Distilled into a variety of products (e.g. glues, primers)	Crude tall oil
	Process fuel in the pulp mill lime kiln	Crude tall oil (typically lower quality)
	Used as petroleum extraction drilling fluid or in phosphate mining	Crude tall oil
Fatty acids	Animal feed	High quality fatty acids
	Oleochemical products (detergents, soap, cosmetics etc.)	All fatty acids
	Recycled paper de-inking	All fatty acids

[140] 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.

For **forestry biomass,** the level of competition varies by type of raw material, cultivation and extraction method, and sector. A new production forest specifically developed for bioenergy purposes is probably not competing with other sectors, although the previous land use would have to be assessed. On the other hand, if forest biomass is harvested from existing production forests, with common harvesting methods, this could imply competition with timber, pulp and paper or other existing forestry industry application. However, a significant portion of forestry residues (>90%) are currently left in such forests and could (if harvested/extracted to a sustainable limit) be used for bioenergy purposes without competition.[141] Woody farm residues are not currently collected as there is no market demand, and so are usually burnt (at farm) or landfilled. Ecofys (2013[142]) estimated that a total of around 126 million m^3 (or 63 million oven dried tonnes) of low ILUC material from woody residues from forests and farms is available for use in bioenergy purposes. ICCT 2013[143] comes to an estimate of around 40 Mtonne of sustainable forestry residues being available in 2011, which they assume is relatively stable towards 2030. This is lower than the Ecofys estimate of sustainably available forestry residue material.

A share of **straw** can be sustainably removed from the field for use as bioenergy feedstock. However, some straw has to be left in the field to maintain soil quality (structure and carbon). The sustainable removal rate depends on local conditions and crop rotations. 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,[144] an estimated total of 21.4 Mtonne of low ILUC cereal straw[145] was available in the EU (top 12 straw producing Member States) in 2013. ICCT 2014[141] looked at a wider range of crop residues (including more crops, but also other residues). They come to an estimate of 122 Mtonne of crop residues available in Europe for bioenergy purposes (for the year 2011). They analysed a total residue production of 367 Mtonne in Europe, of which 122 Mtonne should be left in the field for sustainability reasons and 122 Mtonne is already dedicated to other uses. The Cerulogy study also included the whole of the EU, while the Ecofys study focused on the top 12 straw producing Member States.

An estimated 90% of the currently collected EU supply of **used cooking oil (UCO)** is used for biofuel or bioenergy production,[146] with the balance being used in the oleochemical industry.[147] Importantly, use of UCO as animal feed has been restricted in the EU since 2002 as a reaction to the BSE[148] 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

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[141] ICCT 2014, Wasted: Europe's untapped resource, available at http://theicct.org/wasted-europes-untapped-resource-report

[142] Ecofys 2013, Low ILUC potential of wastes and residues for biofuels. Note that thousand m^3 can be converted to oven dried tonne (odt) by using an approximate conversion of 1,000 m^3 to 500 odt.

[143] ICCT 2013, Availability of cellulosic residues and wastes in the EU", Searle S and Malins C, 2013 International Council on Clean Transportation.

[144] Ecofys 2013, Low ILUC potential of wastes and residues for biofuels

[145] 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").

[146] Ecofys 2013, Low ILUC potential of wastes and residues for biofuels

[147] UCO is not a preferred feedstock for the oleochemical industry, which requires oils with a consistent carbon chain length and saturation.

[148] Bovine spongiform encephalopathy (BSE) is an animal disease also known as "mad cow" disease.

some overseas markets (including in China), although the USA is a notable exception where around 0.3 Mtonne are used annually.[149] There is room for increased use without severe competition with other current uses, in particular as in many markets there is still significant potential to scale up the collection of UCO. Altogether, an estimated 2 Mtonne of UCO sourced could be processed into biofuel in the EU-27 with a low ILUC risk (based on an assessment of the EU, USA, China, Indonesia and Argentina).

For **animal fats,**[150] almost 60% of the EU supply of 2.15 Mtonne Category 3 animal fats was used in the oleochemical industry or as animal feed in 2016 (latest publicly available data).[151] Around 0.43 Mtonne (20%) was used for biodiesel production. 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. Overall, 80% of the available Category 1 and 2 animal fats (0.6 Mtonne) is already used for biofuel production, the remainder being used as a process fuel at the rendering facility. Competition with other uses is 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 4 ktonne).

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[152]. 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 the 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.[153]

For **fatty acids** there is considerable current use in oleochemical and animal feed sectors.[154] Of the estimated total available quantity of fatty acids in the EU (about 3 Mtonne) around 1.5 Mtonne is produced and directly used in the oleochemical sector and about 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, ICCT 2014[141] also estimated the amount of waste available. They concluded that about 17 Mtonne a year of paper waste is estimated to be sustainably available, reducing to around

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[149] Render Magazine, National Renderers Association, Market Report 2016, Ups and Downs all round

[150] 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.

[151] European Fat Processors and Renderers Association (EFPRA), June 2017, Statistical overview of the Animal By-Products Industry in the EU in 2016

[152] These include additives, adhesives, metal working fluids, resins and rubber emulsifiers.

[153] 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

[154] Ecofys, 2016, Assessment of fatty acids, confidential report

12 Mtonne annually by 2030 as recycling rates improve. About 6 Mtonne a year of wood waste is estimated to be sustainably available in 2030. Food and garden waste amount to around 50 Mtonne per year. Recycling and composting are likely to increase in future years, such that around 44 Mtonne of household and garden waste is estimated to be available in 2030. Using the estimates of wastes, forestry residues, crop residues and current consumption of UCO the ICCT study estimates that a sustainable potential of 223 to 225 Mtonne of biomass feedstock would be available for advanced biofuels.

From this analysis it is clear that bioenergy applications often compete with other biomass using sectors. Many waste and residue streams have some other applications besides bioenergy. This implies that it will become costlier for those 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 in time. Low ILUC approaches can help to increase the application of bioenergy crops, without increasing the impacts on other biomass using sectors.

Appendix A Share of biodegradable fraction of waste

Table 21. Overview of reported information by Member States on the share of biodegradable fraction of waste used for energy production.

Member State	Renewable fraction	Manner used for estimation and any steps taken to improve estimates
Austria	N/A	The share of biodegradable fraction of waste is determined based on information from E-Control (no reference provided), which in turn is based on spot checks, the geographical scope of which is to be expanded. No mention of actions to improve the estimation methods.
Belgium	47.78% (Flanders) 47% (Wallonia)	For Flanders, the share of biodegradable fraction of waste is estimated with the selective dissolution method following CEN/TS 15440 (Vito, April 2009)[155]. For Wallonia share based on ICEDD, energy report 2013. This share is determined on the basis of the 'Carbon-14' method in accordance with the current standards. No mention of actions to improve estimation methods.
Bulgaria	N/A	The Methodology for Determining the Morphological Composition of Household Waste applies during the reporting period, which is based on morphological analysis. The methodology has been published on the website of the MOSV[156] and ensures a single approach for determining and forecasting the quantity and morphological composition of the household waste. No mention of actions to improve estimation methods.
Croatia		
Cyprus	N/A	In the two-year period 2015-2016, waste (dried sewage sludge, ASF, RDF, tyres) was used by the cement production industry to generate heating. The biomass fraction of specific alternative fuels was determined by analyses carried out by laboratories accredited according to EN ISO/IEC 17025. No mention is made on the exact method used for estimating, nor are actions mentioned to improve estimation methods.
Czech Republic	N/A	Regulation No 477/2012 determining the types and parameters of renewable sources supported for electricity, heat or biomethane production, makes use of consultation and information from the IEA, Eurostat, other EU countries, and information from local operators of municipal waste incinerators. No mention is made on the exact method used for estimating, nor are actions mentioned to improve estimation methods.
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.

[155] https://esites.vito.be/sites/reflabos/onderzoeksrapporten/Online%20documenten/rapport_aandeel_hernieuwbaar_maart%202011.pdf

[156] http://www.moew.government.bg/bg/otpaduci/bitovi-otpaduci/

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Member State	Renewable fraction	Manner used for estimation and any steps taken to improve estimates
Estonia	64.66%	Estonia has regularly conducted studies on the sorting of mixed municipal waste (the Ministry of the Environment has commissioned such a study every two/three years), which provide a good overview of the share of biodegradable waste and its changes. No mention is made on the exact method used for estimating, nor are actions mentioned to improve estimation methods.
Finland	50%	Estimated based on sample survey, with no clear indication of the method used by survey respondents for the estimation of the share. As an action for improvement, a composition database was set up to increase the number of samples for the survey.
France	50%	The estimated share was based on the suggestion by EUROSTAT. No steps to improve the estimate have been taken.
Germany	50%	This value comes from a study (UBA, 2011[157]) 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	Waste is only used for biogas production; therefore, no share has been estimated or actions identified to improve this estimation.
Hungary[158]	N/A	Not method for estimation of the share is specified nor are actions mentioned to improve this estimation.
Ireland	N/A	CEN has published a technical standard that deals with the determination of biomass content in solid recovered fuels. The CEN/TS 15440 standard is used to estimate the biodegradable share of waste in cement plants in Ireland. The recognised CEN standard for the calculation of the biomass content in the case of waste-to-energy is BS EN 15440:2011 - Solid Recovered Fuel, Methods for the Determination of Biomass Content. This standard specifies a number of methodologies namely, the selective dissolution method, the manual sorting method and the carbon 14 method. The CRU, as administrator of the PSO in Ireland, is currently drafting proposals on several potential methodologies for calculating the renewable energy fraction of waste in the context of the above standard. So no method has been selected yet, nor are actions to improve the estimation specified.
Italy	50%-51%	Incentives for electricity from biodegradable waste are calculated in two alternative ways under national law: - fixed rates for certain categories of waste. - analytical determination methods for the remaining waste. This fixed rate (very similar to the share considered for statistical purposes) was established through a testing campaign conducted on the municipal waste used by a representative sample of waste-to-energy plants. For waste other than municipal waste, the incentive is

[157] https://www.umweltbundesamt.de/sites/default/files/medien/461/publikationen/4116.pdf

[158] Hungary did not indicate a share, but only the total amount of energy related to waste-to-energy production. Hungary did not comment on how the share was established.

Member State	Renewable fraction	Manner used for estimation and any steps taken to improve estimates
		calculated on the basis of test results, in accordance with European technical standards (C14, selective dissolution, product analysis). No actions are mentioned to improve the estimation.
Latvia	N/A	Only waste streams are used for biogas production. No steps have been taken to improve the manner to estimate the share.
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	No change compared to previous Progress Report (which states that they use surveys in which the fraction of biodegradable carbon is estimated). No actions are mentioned to improve the estimation.
Malta	100%	Since all waste-to-energy currently comes from anaerobic digestion, the share is 100%. Shares of biodegradable content are set in the Waste Management Plan for the Maltese Islands for different types of waste (e.g. in mixed municipal waste it is 66%). No exact method for estimation of the share is mentioned, nor are actions to improve the estimation.
Netherlands	55%	The estimate of the share of biodegradable waste is made annually by an independent organisation, the Rijkswaterstaat Environment, using the annual report of the Waste Recording working group[159]. 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. No actions are mentioned to improve the estimation.
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	56.26 %	No energy from waste in 2015/2016. The share of biodegradable waste is determined in the Annual Environmental Status Report for 2015. No details on the method for estimation are provided in the progress report. No actions are mentioned to improve the estimation.
Slovakia	50-55%	Determined directly by companies involved in recovering energy from waste. These data are recorded and sent to the Statistical Office. No details on methodology for estimation nor on actions to improve such estimations are provided.

[159] http://english.rvo.nl/file/enina-update-2016

Member State	Renewable fraction	Manner used for estimation and any steps taken to improve estimates
Slovenia	N/A	Currently production of energy from waste is low. The share of biodegradable waste in all waste used for energy generation is estimated for the purpose of reporting to UNFCCC, and in the future the same methodology will also be used to monitor the use of waste in the production of energy from RES. No details on methodology for estimation nor on actions to improve such estimations are 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	60% in 2015 52% in 2016	The 2015 estimate was based on two studies[160] done, on a sample of plants in Sweden. Two types of methods are mentioned, namely the analyses of solid waste and the analyses of the flue gases formed during incineration. In 2017 one of the studies was updated to obtain a new estimate. No other actions are mentioned to improve the estimation.
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[161] 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.

[160] 'Analysis of the renewable proportion of waste for incineration in Sweden with reference to energy content', Profu (2008).

[161] https://www.ofgem.gov.uk/publications-and-updates/renewables-obligation-fuel-measurement-and-sampling-guidance

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.

MS	Domestic vs import	Direct supply of wood biomass from forests		Indirect supply of wood biomass		Energy crops and short rotation trees		Agrr by-products / processed residues		Biomass from waste		Others	
		2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
AU	Domestic	8 800 000	8 900 000	8 700 000	9 200 000	30 500	30 300			729 039	703 510	2 199 922	1 932 982
	EU	1 200 000	1 200 000	5 500 000	5 700 000					0	0	0	0
	Non EU	0	0	300 000	300 000								
BE	Domestic	1 972 678	2 424 831	3 405 359	3 485 285	20 521	1 268	558 697	728 283	4 497 939	5 070 923	179 206	187 993
	EU	0	0	643 080	606 924	2 171	1 721	22 664	9 156	0	0	179 206	187 993
	Non EU	0	0	858 859	1 635 134	59 472	43 797	0	0	0	0	0	0
BU	Domestic	4 263 307	4 487 807	99 423	79 567	197 289	226 409			12 755	12 486		
	EU	1 821	1 470										
	Non EU	455											
CY	Domestic (tn)	2096	2096	2411	3399	0	0	4586	4641	671	732		
	EU (tn)	525,632	360,879	1050	861	0	0	0	0	13 791	14 313	0	0
	Non EU (tn)	1 165.42	888.14	16 150	15285	0	0	0	0	0	0	0	0
CZ	Domestic	5 605	5 685	4 104	4 037	372	386	5 173	5 181	4 387	4 415	0	0
	EU	2	3	470	701	0	0	0	0	0	0	0	0
	Non EU	4	5	36	40	0	0	0	0	0	0	0	0
DK	Domestic (tn)	2 627	2 648	793	668	0	0	1 360	1 355	787	1815		
	EU (tn)	464	701	1 555	1 896					7	7		
	Non EU (tn)	41	134	381	465								
EE	Domestic (in 1000m^3)	3572	3864	2970	3629								
	EU (in 1000m^3)	5	10	137	128								
	Non EU (in 1000m^3)	2	1	27	21								
FI	Domestic (TJ)	110 648	115 301	220 291	233 811					11 420	12 939		
	EU (TJ)	39	55	96	19								
	Non EU (TJ)	158	199	909	825								
FR	Domestic	46 685 400	51 061 200	*(combined with direct)*				448 ktoe	448 ktoe	1 610 ktoe	1 598 ktoe		
	Imported	838 026	973 040	1 252 798	1 692 400								
DE	Domestic	24 602	23 452	11 870	11 315	N/A	N/A	53 605	53 574	6 285 ktoe	6 382 ktoe	156	149
	EU	79	75	79	75	N/A	N/A	0	0	0	0	0	0
	Non EU	4 915	4 685	4 049	3 860	N/A	N/A	0	0	2 822	2 700	48	46
EL	Domestic	721 338	604 644	65 973	85 330			1 961 037	1 400 658	8 552	4 182		
	EU	122 835	123 757	21 174	27 527								
	Non EU	26 486	6 027	5 494	4 213								
HU	Domestic	3 279 907 m^3 firewood 2 943 tonnes pellets 2 856 tonnes wooden briquettes	3 225 687 m^3 firewood 2 390 tonnes pellets 2 801 tonnes wooden briquettes	34 392 m^3 of waste	151 098 m^3 of waste	72 387 m^3	14 351 m^3	N/A	N/A	77 356 tonnes	136 653 tonnes	N/A	N/A
	EU	29 544 m^3 firewood 1 072 tonnes pellets 4 337 tonnes wooden briquettes	31 844 m^3 firewood 1 760 tonnes pellets 8 077 tonnes wooden briquettes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Non EU	117 790 m^3 firewood 7 669 tonnes pellets 2 147 tonnes wooden briquettes	133 910 m^3 firewood 11 697 tonnes pellets 9 176 tonnes wooden briquettes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
IE	Domestic	343 000 m^3	345 000 m^3	441 200 m^3	573 000 m^3	5 000 m^3	20 000 m^3	33 906 tonnes	34 721 tonnes	434 139	461 108	230 000 m^3 PCRW	235 000 m^3 PCRW
	EU	8 000 m^3	6 000 m^3	0	0								
	Non EU	0	0	0	0			124 800 m^3	241 200 m^3				
IT	Domestic (tn)	17 285 564	16 889 387	2 454 428	2 224 963	5 437 882	5 397 006	4 872 541	5 069 681	5 927 766	6 060 572		
	EU (tn)	836 648	779 565	1 579 980	1 680 639	76 694	106 263				3 136		
	Non EU (tn)	427 143	417 287	554 896	429 344	812 880	700 630			3 896			

MS	Domestic vs import	Direct supply of wood biomass from forests		Indirect supply of wood biomass		Energy crops and short rotation trees		Agrr by-products / processed residues		Biomass from waste		Others	
		2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
LV	Domestic	3434 m^3 firewood 51 tn wood briquettes 1 577 wood pellets	3324 m^3 firewood 45 tn wood briquettes 1 517 wood pellets	3 872 m^3 wood waste 6 282 m^3 wood chips	4 138 m^3 wood waste 7 459 m^3 wood chips			9 tn	10 tn	18 mln m^3 landfill gas 4 mln m^3 sewadge sludge	17 mln m^3 landfill gas 5 mln m^3 sewadge sludge	170 mln m^3	174 mln m^3
	EU	6 m^3 firewood 2 tn wood briquettes 127 wood pellets	6 m^3 firewood 7 tn wood briquettes 171 wood pellets	15 m^3 wood waste 498 m^3 wood chips	114 m^3 wood waste 507 m^3 wood chips								
	Non EU	157 m^3 firewood 23 tn wood briquettes 1 553 wood pellets	157 m^3 firewood 20 tn wood briquettes 1 627 wood pellets	345 m^3 wood waste 992 m^3 wood chips	453 m^3 wood waste 1779 m^3 wood chips								
LT	Domestic	251.1 felling waste 662.1 fuel wood	248.3 felling waste 628.3 fuel wood					39.9	40.3	28 087 landfilled waste 11 346 waste to energy	10 522 landfilled waste 17 664 waste to energy		
	No information on imported biomass provided												
LU	Domestic					14 088	13 606						
	No information on imported biomass provided												
MT	Domestic							28 087 tons	27 293 tons	187 582 tons	159 569 tons		
	EU	732.1	451.0	936.5	869.5								
	Non EU	0.0	44.0	1413.2	1552.1								
NL	Domestic	2 251 033	2 229 787	2 126 739 tonne	2 221 986 tonne	25 821 tonne	25 042 tonne	5 130 464 tonne	5 204 522 tonne	7 839 752 tonne	7 904 644 tonne		
	No information on imported biomass provided												
PL	Domestic	21 527 588	21 739 154			305 863	311 519	1 337 240	812 974	4 252 975	4 343 793	88 358	252 171
	EU	238 184	170 006					27 278	34 170				
	Non EU	1 776 674	2 164 851					519 532	107 443				
PT	Domestic	955	1 092	4 691	4 688			13	0	1 171 kton MSW 152 639 731 m^3 biogas	1 199 kton MSW 145 642 447 m^3 biogas		
	EU	7	3	0	12			7	0				
	Non EU												
RO	Domestic			14 429	14 691	8.0	8.2	N/A	N/A	N/A	N/A	0	0
	No information on imported biomass provided												
SK	Domestic	1 460 000 m^3	1 440 000 m^3	1 025 000 t	1 007 000 t	490 000 m3	460 000 m3	0	0	67 000 t	64 000 t		
	EU	10 000 m^3	10 000 m^3	0	0	0	0						
	Non EU	12 600 m^3	10 300 m^3	25 000 t	23 000 t	0	0						
SL	Domestic	1 242 229 m^3	1 271 712 m^3							199 893 tonnes	164 604 tonnes		
	EU	62 302 m^3	62 655 m^3										
	Non EU	89 324 m^3	121 716 m^3										
ES	Domestic	5 924 730	5 969 581	5 239 238	5 278 900			5 805 452	5 738 365	7 357 930	7 116 548		
	No information on imported biomass provided												
SE	Domestic (1000 tonnes	5 369	5 629	19 984	19 766	27	38	132	152	2 826	2 700	534	446
	EU (1000 tonnes DW)	4	6	316	226			29	38	321	278		
	Non EU (1000 tonnes D\	4	5	462	1 072			18	18	308	267		
UK	***No information in tabular format provided***												

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

		Common arable crops for biofuels		Energy crops		Others	
		2015	2016	2015	2016	2015	2016
AU	Domestic	38 400 (ethanol) 4 600 (biodiesel)	59 700 (ethanol) 17 400 (biodiesel)				
	EU	51 200 (ethanol) 601 300 (biodiesel)	27 300 (ethanol) 489 600 (biodiesel)				
	Non EU	0	0				
BE	Domestic	239 288	239 325				
	EU	1 151 464	1 176 400				
	Non EU	39	0				
BU	***No information provided***						
	Non EU						
CY	Domestic (MT)	0	0	0	0	73 (UCO)	56 (UCO)
	EU (MT)	3944	604	0	0	3109 (UCO)	5246 (UCO)
	Non EU (MT	0	0	0	0	3527 (UCO)	4015 (UCO)
CZ	Domestic	N/A	N/A	0	0	0	0
	EU	N/A	N/A	0	0	0	0
	Non EU	N/A	N/A	0	0	0	0
DK	***No information provided***						
EE	***No information provided***						
FI	***No information provided***						
FR	Domestic (ktoe)	2 434	1 411				
	Imported (ktoe)	461	1 346				
DE	Domestic	2 687	1 895	0	0	168 ktoe	168 ktoe
	EU	4 257	3 683	0	0	251 ktoe	371 ktoe
	Non EU	1 387	2 012	0	0	111 ktoe	246 ktoe
EL	Domestic		33 k tn sunflow er 1 k tn rapeseed 15 k tn soy bean			61 ktn cotton seed 18 ktn UCO & animal fats	60 ktn cotton seed 24 ktn UCOs and animal fats
	EU		<0.9 ktoe biodiesel sunflow er 8 ktoe biodiesel rapeseed				0.8 ktoe biodiesel from UCOs
	Non EU		<0.9 ktoe biodiesel (rapeseed) <0.9 ktoe biodiesel (palmoil)				
HU	Domestic	337 503 tonnes rapeseed 1 253 001 tonnes maize	325 006 tonnes rapeseed 1 350 007 tonnes maize			31 000 tonnes (UCO)	30 000 tonnes (UCO)
IE	Domestic	Rapeseed 62,509 litres	0			19.25 mln litres (UCO & tallow)	25 mln litres (UCO & tallow)
IT	Domestic	532	999			76 384	89 896
	EU	26 108	20 850			35 463	43 315
	Non EU	357 843	131 577			3 844	70 880
LV	Domestic	3 (bioethanol) 66 (biodiesel)	5 (bioethanol) 45 (biodiesel)				
	EU	11 (bioethanol) 17 (biodiesel)	11 (bioethanol) 6 (biodiesel)				
	Non EU	2 (bioethanol) 60 (biodiesel)	3 (bioethanol) 47 (biodiesel)				
LT	Domestic	365 (rapeseed) 60 (cereal grain)	320 (rapeseed) 49 (cereal grain)				
LU	***No information provided***						
MT	***No information provided***						
NL	***No information provided***						
PL	***No information provided***						
PT	***No information provided***						
RO	Domestic	475	540	N/A	N/A	0	0
SK	Domestic	Rapeseed 209 655 t Maize 87 600 t	Rapeseed 220 090 t Maize 143 400 t	0	0		
	EU	N/A	N/A	0	0		
	Non EU	N/A	N/A	0	0		
SL	***No information provided***						
ES	***No information provided***						
SE	Domestic (ktoe)	42	12			88 biomass based w aste 81 residues paper & pulp	63 biomass based w aste 35 residues paper & pulp
	EU (ktoe)	334	239			11 biomass based w aste 390 residues paper & pulp	1 biomass based w aste 468 residues paper & pulp
	Non EU (ktoe)	114	69			2 biomass based w aste 127 residues paper & pulp	1 biomass based w aste 466 residues paper & pulp
UK	***No information in tabular format provided***						

Appendix C Local environmental impacts related to biofuels

In the following section, we present the results from the analysis of local environmental impacts for the main crop-country combinations as identified as suppliers of feedstock for biofuel consumption in the EU.

C.1 Introduction and methodological notes

In the following section, we present the results from the analysis of local environmental impacts for the main crop-country combinations as identified as suppliers of feedstock for biofuel consumption in the EU. The methodological approach varies somewhat between the different crop-country combinations analysed. For the crops cultivated within the EU itself (SectionC2), the assessment is primarily based on analysis of developments in selected indicators of environmental status, as found in publications by Eurostat and the European Environment Agency (EEA). For the assessment of the non-EU crop-country combinations (Sections C3-C5), the approach is based on reviews of the scientific literature on the topic at hand. In order to capture more recent findings and developments, focus of the literature review is on research published after 2014.

A substantial challenge in doing generalized analyses of the environmental impacts of biofuels is the large heterogeneity among different supply chains. Site-specificity is central when it comes to determining the actual local environmental impact, but the general lack of transparency in agricultural commodity supply chains makes it in most cases very difficult to trace the origin of feedstock in satisfactory detail. The use of country-level data for feedstock origin is especially problematic in countries like Brazil, where conditions pertaining to climate and ecosystem characteristics vary widely between regions. This means that it may not always be straightforward to extrapolate findings from studies conducted in one particular geographical location to region or country level[162]. For certain aspects, country borders are of substantially less importance compared to boundaries set by the natural geography. This is especially important for issues pertaining to waters, where river basins are a more appropriate analytical focus (Flach et al., 2016).

In addition to heterogeneity in environmental conditions, another question concerns whether cultivation systems and management practices used for EU biofuel feedstock differ in any significant way from modus operandi in general for the particular crop and country. A key factor in this discussion is that feedstock for biofuels used in the European Union has to adhere to the sustainability criteria laid out in the 2009 Renewable Energy Directive (2009/28/EC), the 2014 decision on highly biodiverse grasslands (Commission Regulation (EU) No 1307/2014) and the 2015 ILUC directive (EU/2015/1513). In addition, the voluntary schemes used to certify that feedstock adheres to the RED

[162] For the Brazilian case, we have attempted to address this issue by focusing our analysis on the Cerrado biome, where soybean cultivation currently is expanding most strongly.

criteria may have additional sets of criteria, including such that specifically address local environmental impacts. However, it is difficult to obtain a precise estimate of this effect as different schemes have different criteria and there is a lack of transparency in terms of biofuel volumes certified by each scheme (ECA, 2016). It should also be noted that for e.g., oil palm supply chains, certification has shown to have rather limited effectiveness in addressing local environmental problems (Carlson et al., 2018; ECA, 2016; Larsen et al., 2018; Morgans et al., 2018).

As this report is the most recent in a series of biennial assessments on the progress of EU renewable energy and biofuel sustainability, each section begins with an overview of the conclusions from the previous reports so as to strengthen the continuity between the reports and facilitate comparisons over time.

C.2 EU agricultural crops (Wheat/maize/sugar beet/rapeseed)

Background

The majority of the feedstock used for biofuels consumed in the EU is also grown within the EU and this is true for bioethanol as well as biodiesel. All EU Member States have to report every two years on their national developments in the field of renewable energy, as described in the Renewable Energy Directive. A component of this reporting is to provide information on the impact of domestic biofuel feedstock cultivation on air/soil/water quality and biodiversity. In the reports for 2015-2016[163] however, most Member States provide very little information on this topic. The reasons given for the sparse information is either a) that no or negligible amount of biofuel feedstock is cultivated domestically, b) that it is not possible to distinguish between crops grown for biofuels and crops for other purposes or c) that no information on recent developments is available. Only Germany and Sweden provide more detailed information, but these do not give much information on the developments in the most recent period.

Water

Findings from previous Progress Reports

The *2011 biofuels baseline report* highlights nutrient leaching and pesticide pollution as particularly important water quality risks pertaining to biofuel feedstock cultivated in the EU. Risks related to pesticides and nutrient leaching are emphasized especially for maize and rapeseed. These two, along with sugar beet, are also highlighted as high-risk when it comes to nutrient leaching. The 2012 Renewable Energy Progress and Biofuels Sustainability report only does in-depth analysis of countries and crops deemed to be at high risk in terms of water quality, and no EU grown crops are included in these.[164]

The 2014 Renewable Energy Progress and Biofuels Sustainability report notes that the EU has relatively strict regulations pertaining to the use of pesticides and fertilizers,[165] but that EU grown maize and wheat are

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

[164] https://ec.europa.eu/energy/sites/ener/files/documents/2013_renewable_energy_progress.pdf

[165] https://ec.europa.eu/energy/sites/ener/files/documents/Final%20report%20-November%202014.pdf

comparatively low-yielding which means that the impact per energy unit of biofuel can still be rather high. It is worth noting that the soil erosion risks connected with sugar beets can also affect water quality. The 2016 Report on Renewable Energy (Oeko-Institut, 2017) does a more in-depth analysis of water aspects only of non-EU crops[166].

Our assessment

The 2000 EU Water Framework Directive (2000/60/EC) is the central governance structure when it comes to water quality issues in the European Union. The aim of the Water Framework Directive (WFD) is that all EU water bodies – ground water and surface water – should achieve "good status", which means that water quality should be very close to what would be the case without human impact. Currently, about 40% of European surface water bodies are of "good" or "high" status, a share that has remained fairly stable over time since the WFD was adopted. However, the status classification is a composite indicator and many water bodies have seen significant improvements in different individual indicators (EEA, 2018).

Agriculture in general and crop cultivation in particular are highly important factors when it comes to the environmental status of European waters. Grain crop cultivation in Europe is primarily rainfed and dependent on seasonal patterns of precipitation, although maize is commonly irrigated in the Mediterranean region (Eurostat, 2018) which can make up much of the water footprint of EU biofuel feedstock (Berger et al., 2015).

Agriculture is also a large source of negative impacts on surface waters as well as ground water bodies. Effects from emissions of nutrients - especially nitrates - and pesticides are particularly important. Nitrate emissions have seen significant downward trends in the last decades, following implementation of different forms of farm-level measures such as establishment of buffer strips, changes in crop rotation systems and improved fertilizer management. Having said this, there are large variations between Member States and there are indications that downward trends in fertilizer use are levelling off (DG ENV, 2018).

Only 38% of surface waters in the EU is classified as "good" or better in terms of chemical status. The share would be about 97% were it not for a small number of substances that are very widespread, including mercury (EEA, 2018). In terms of pesticides, strengthened governance (including bans on particular substances) and management appear to have had effect in reducing chemical pressures on surface waters (EEA, 2018). In the last two decades there have been substantial reductions in terms of risks pertaining to pesticides. A strategy for further action was laid out in the 2009 Directive on sustainable use of pesticides (2009/128/EC). Implementation of the directive is in its early phases with governance structures in the process of being set up, so it is too soon to observe its effects (DG Health and Food Safety, 2017).

[166] Reference

Soil

Findings from previous Progress Reports

The *2011 biofuels baseline report* emphasizes that it is difficult to directly attribute developments in overall EU soil quality to cultivation of biofuel feedstock. The conditions across countries vary widely, crops are grown for many purposes other than biofuels and crop rotation systems indicate that a particular field may have been used for a several different crops over a given number of seasons. The overall risk level is deemed to be "low-medium" with erosion and compaction as the key problems. In terms of soil risks, pesticide leakage to soils is deemed the most problematic for rapeseed and maize. Maize is also deemed at high risk of erosion and the same goes for sugar beet, in both cases this is a consequence of extensive periods in which soils are left bare. Soil compaction is in general not seen as a serious problem for EU crops except for sugar beet which is classified as a "high risk" crop when it comes to soil compaction. The 2012 Renewable Energy Progress and Biofuels Sustainability report discusses soil quality aspects pertaining to EU cultivation of biofuel feedstock based on set of different indicators, see Table 24.

Table 24. Soil quality characteristics of different EU crops, according to the 2012 Renewable Energy Progress and Biofuels Sustainability report.

Crop	Erosion	Compaction	Contamination	SOC loss
Rapeseed	Medium or high (UK)	Low or medium (UK)	High	Medium
Sugar beet	High or medium (UK)	High or low (UK)	High	Medium
Maize	Medium-high	High	High	Medium
Wheat	Low	High	High	Medium
Rapeseed	Medium or high (UK)	Low or medium (UK)	High	Medium

The 2014 Renewable Energy Progress and Biofuels Sustainability report notes that expansion of sugar beet and maize in the EU could increase risks of soil erosion, resulting from how these crops are cultivated. Crops grown over the winter (winter wheat & winter rapeseed) provide good crop cover, thereby reducing erosion risks. EU crops are not included in the in-depth analysis of soil aspects in the 2016 Report on Renewable Energy (Oeko-Institut, 2017).

Our assessment

Water erosion and wind erosion are both serious problems for European soils, with water erosion affecting more than 15% of the whole land area of Europe (excluding Russia), and wind erosion affecting up to 5%. Erosion is a serious problem that, if not mitigated, can have detrimental effects on landscapes and conditions for agriculture. A typical example of this is the Mediterranean region, where in some parts centuries of erosion have resulted in a complete loss of topsoil (Jones et al., 2012).

Water erosion is especially prevalent during bursts of heavy rainfall (Jones et al., 2012). This means that water erosion tends to be a rather seasonally concentrated phenomenon, where heavy erosion can occur over rather short periods of time (Panagos et al., 2016). Wind erosion occurs in many parts of Europe, with the highest loss rates found on sandy soils in the countries around the North Sea and the Black Sea (Borrelli et al., 2017).

Identification and estimation of trends and developments of soil erosion rates is complicated and usually done by the use of modelling tools. A fairly recent assessment of the extent of water erosion in Europe found that water erosion rates on arable land in Europe had declined by about 20% over the time period 2000-2010. Improved farming practices, including reduced tillage and the use of cover crops, is identified as a key reason for this positive trend (Panagos et al., 2015; Pennock et al., 2015).

In terms of effects from pesticides on soils, the general trend is of reduced pressure as some highly toxic substances have been phased out. However, residues from past applications can remain in the soil for quite some time (DG Health and Food Safety, 2017).

Air

Findings from previous Progress Reports

The *2011 biofuels baseline* report identifies that there is a lack of information pertaining to the occurrence of air pollution of crop cultivation in the EU. In the 2012 Renewable Energy Progress and Biofuels Sustainability report, air pollution risks in the EU are deemed to be high in the cultivation stage of the supply for all analysed crops, including rapeseed, sugar beet, wheat and maize. The key risk factors underlying this are all related to the use of agrochemicals, including NOx and NH3 emissions from fertilized soils. The risks pertaining to NH3 and NOx emissions from fertilized soils are reiterated in the 2014 Renewable Energy Progress and Biofuels Sustainability report, where improved nitrogen use efficiency is identified as an important means of mitigation. It is noted that NOx emissions from agriculture have increased by 5% in the period 2002-2011. The 2016 Report on Renewable Energy (Oeko-Institut, 2017) does not do a more in-depth analysis of air quality aspects.

Our assessment

In general, emissions of air pollutants in the EU have maintained a downward trend since the early 2000s. However, the last couple of years have seen this trend level out for several substances, see Figure 33 and Figure 34 below. Perhaps most notably and especially relevant herein is that NH_3 emissions, 94% of which originate in the agricultural sector, have actually grown since around 2013 after a decade of slow decline.

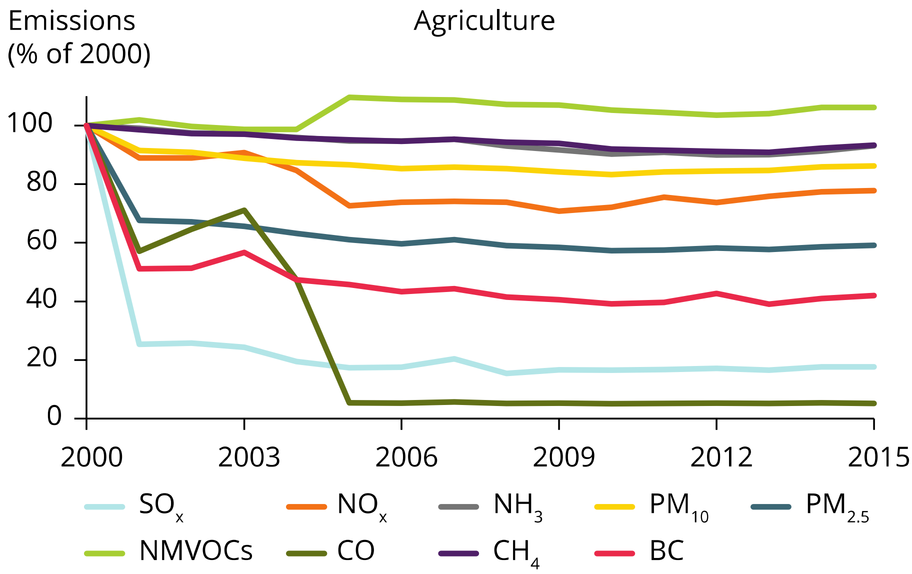

Figure 33. Emissions of selected substances 2000-2015, in percentages of 2000 emissions (EEA, 2017).

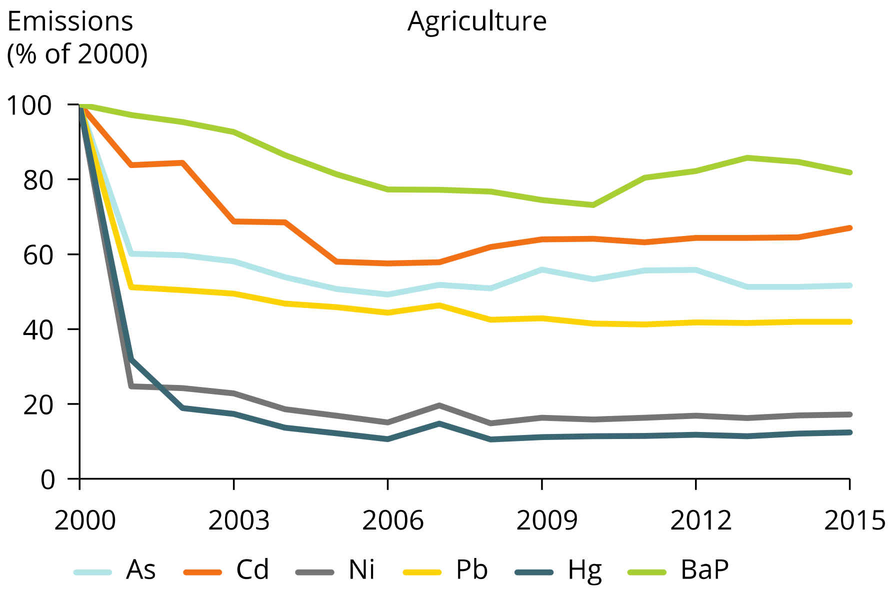

Figure 34. Emissions of selected substances 2000-2015, in percentages of 2000 emissions (EEA, 2017).

NH_3 emissions are problematic because they contribute to increased accumulation of nitrogen compounds in the natural environment but also because NH_3 enable the formation of small particulate matter that in turn can have detrimental health effects (Maas and Grennfelt, 2016). Key reasons for the shifting trend are increased emissions in Italy, the UK and Ireland although Germany, France and Spain make up the top three among EU Member States in terms of NH_3 emissions. Animal manure is the largest agricultural source of NH_3 although emissions from fertilized soils make up more than 40% of the emissions as well (Eurostat, 2017). Improved manure management and more efficient use of nitrogen fertilizer – especially pertaining to urea – are especially important strategies in terms of mitigation of NH_3 emissions (Sanz-Cobena et al., 2014).

In addition to NH_3, soils can also be a substantial source of NO_x emissions (Almaraz et al., 2018; Vinken et al., 2014). Combustion of various forms constitute the biggest source of NO_x, but emissions from road transport and stationary combustion (electricity generation, industry) are decreasing. Agricultural NO_x emissions in the EU are however flat or growing (EEA, 2017) which means that the relative importance of agricultural soils as a NO_x source will grow over time (Sutton et al., 2017).

Biodiversity

Findings from previous Progress Reports

The *2011 biofuels baseline report* assesses biodiversity risks pertaining to EU biofuel feedstock cultivation according to 13 different categories, and the EU is deemed in general to be a "low-risk" region in terms of biodiversity impacts, although it should be noted that this assessment is relative, i.e., compared to other regions whence the EU sources biofuels. The low risk in the EU is largely attributed to the existence of (again, relatively) effective governance systems for biodiversity protection. At the same time, the report acknowledges that cultivation of biofuel crops in the EU contributes to biodiversity loss, largely because of systems based on monocultures with substantial agrochemicals inputs. Sugar beet is deemed more favourable than maize, wheat and rapeseed from a biodiversity perspective. The 2012 Renewable Energy Progress and Biofuels Sustainability report notes that in general biofuels feedstock cultivated in the EU have "much lower risks" of biodiversity loss than most non-EU feedstock and therefore provides in-depth analysis of only a set of non-EU cases. The 2014 Renewable Energy Progress and Biofuels Sustainability report notes that biofuel crop cultivation in the EU is mostly conducted in large-scale monocultural operations. However, it notes also that expansion is most likely to be on existing cropland, which means that biodiversity risks from land use change should not be very prevalent. In addition, there are continuous gradual improvements in terms of efficiency in input use, which should limit risks pertaining to agricultural intensification. The 2016 Report on Renewable Energy (Oeko-Institut, 2017) notes that the vast majority of expansion in crops that are used as biofuel feedstock in the EU over the time period 2007-2014 has taken place on existing cropland, which implies that biodiversity risks from land use change should be rather small.

Our assessment

As noted above, cultivation of biofuel feedstock can have effects on biodiversity in several different ways. Large-scale crop cultivation tends to be carried out in large monocultures that inherently and by design are limited in terms of biodiversity. If establishment of such monocultures replaces more biodiverse habitats such as grasslands or wetlands, this obviously has a negative effect on biodiversity, but the sustainability criteria in the Renewable Energy Directive should limit this type of land conversion. In addition to this effect from land use change, the characteristics of agricultural operations can also affect biodiversity in the field itself but also in adjacent habitats such as streams and hedgerows (Immerzeel et al., 2014).

Long-term trends pertaining to agricultural biodiversity in Europe have largely been negative as a result of agricultural intensification and landscape transformation of various forms. An example of this can be seen in the continuous decline in the Farmland Bird Index (Figure 35), which compiles population trends for common farmland bird species in Europe.

Figure 35. Common bird index in the EU 1990-2014 (Eurostat, 2018).

The downward trend in farmland bird populations and diversity has been connected to a similar but even stronger long-term decline in insect populations in landscapes dominated by crop cultivation. Although the underlying reasons here are not clearly identified, agricultural intensification is suggested as a plausible cause (Hallmann et al., 2017), with increasing focus on the growing use of insecticides based on neonicotinoids (Hallmann et al., 2014). In early 2018, it was announced that three neonicotinoids will be banned in the EU from 2019 onwards (Butler, 2018).

When it comes to land use change there has been much focus in Europe - especially in Germany - on the expansion of maize cultivation for bioenergy purposes onto permanent grasslands and the effects that this has had on biodiversity (Jerrentrup et al., 2017; Sauerbrei et al., 2014). Although it is important to note that this development was largely driven by demand for silage maize used for biogas production, maize has become an important feedstock for bioethanol as well, especially in central Europe (USDA FAS, 2018a).

C.3 Oil palm (Indonesia/Malaysia)

Background

As a source of raw material for vegetable oils, oil palm is in many ways a highly advantageous crop. Its annual yield is far superior to other oil crops, a fact that has contributed greatly to the rapid market growth for palm oil and the concurrent expansion of oil palm cultivation. However, oil palm only grows in tropical areas and its rapid expansion has been a substantial driver of extensive deforestation in Indonesia and Malaysia. The use of palm oil for biofuels has also been heavily debated with both NGOs and researchers questioning the environmental benefits of substituting fossil fuels for biofuels produced from palm oil (Moreno-Peñaranda et al., 2015; e.g., Mukherjee and Sovacool, 2014).

Although much of the focus in the debate has been on carbon balances and climate impact, non-climate environmental impacts have also been widely reported (Larsen et al., 2012; Varkkey, 2012). However, these impacts are to a large extent associated with the conversion of natural forests to oil palm plantation while – as noted in the general introduction – palm oil used for biofuels in the EU has to adhere to the sustainability criteria in the Renewable Energy Directive. This forbids the use of feedstocks from recently (since 2008) deforested lands, and recent deforestation can therefore not be directly linked to biofuels sold on the EU market. Having said this, there are serious concerns about the indirect effects from EU consumption of palm oil-based biofuels on deforestation, triggered by a general increase in demand for palm oil (Scarlat and Dallemand, 2011).

The first half of 2018 saw an intense debate concerning the role of palm oil as a biofuel feedstock in the recast of the RED for the time period 2021-2030. The European parliament wanted to include a rapid and complete phase-out of palm oil as a biofuel feedstock in RED II (Michalopoulos, 2018), a proposal that led to strong protests from Malaysia and Indonesia (Ellis-Petersen, 2018). In the final version of the directive -palm oil was however not singled out explicitly. Instead, the directive includes a phase-out of all “high-iLUC risk” feedstock by 2030, and no expansion of these feedstocks beyond their 2019 levels (EEAS, 2018). The Delegated Regulation adopted by the EC in March 2019 sets out the criteria for determining high ILUC-risk feedstock for biofuels. With parameters included in the Annex to the Regulation, it follows that palm oil is a high ILUC-risk feedstock. The European Parliament and the Council of Ministers have, during a two-month scrutiny period, a right to express an objection to the Regulation.

With this context, the analysis in this section focuses on environmental impacts in the actual management of existing plantations. Note that the analysis cannot distinguish between plantations that actually deliver feedstock for biofuels to the EU market and other plantations, since detailed information on the links between plantations and markets is not available. Rather, the prevailing practices and common risks with oil palm in Indonesia are assessed. Some of the risks identified are however not relevant for palm oil biodiesel sold in the EU as some of the voluntary schemes that are used to guarantee compliance with the Directive do cover some of the risks analysed in this chapter (Kemper and Partzsch, 2018).

Water

Summary of the previous Progress Reports

The *2011 biofuels baseline report* notes that water quality issues pertaining to oil palm cultivation in Indonesia and Malaysia relate to a number of different aspects. These include erosion and associated siltation of waterways and pollution from agrochemicals such as fertilizers and pesticides. Especially noteworthy is the widespread use of the pesticide *Paraquat*, which is toxic to humans and banned for agricultural use in several EU Member States. The 2012 Renewable Energy Progress and Biofuels Sustainability report notes that palm oil from Indonesia and Malaysia has some of the highest risks in terms of water quality impacts among the crop-country combinations analysed. In addition to the factors mentioned in the *Baseline report*, effluent from palm oil processing is also mentioned as one important factor. The report also notes that there are large differences between Malaysia and Indonesia when it comes to fertilizer intensity. The 2014 Renewable Energy Progress and Biofuels Sustainability report reiterates the threats to water quality from soil erosion and agrochemicals and emphasizes the significant lack of information on pesticide use in oil palm plantations. The report further highlights the problems associated with emissions from palm oil mill effluents (POME) from palm oil processing. The 2016 Report on Renewable Energy (Oeko-Institut, 2017) does not include any specific assessment of water quality aspects.

Table 25 below summarizes key impacts on water quality from palm oil, as identified by the previous Progress Reports.

Table 25. Key impacts on water quality from oil palm cultivation and processing as identified in previous Renewable Energy Progress Reports.

Phase	*Establishment/land use change*	*Agricultural operation*	*Processing*
Impact	Soil erosion & siltation	Agrochemicals, esp. pesticides	Palm oil mill effluent pollution

Our assessment

In Malaysia and especially Indonesia, fresh water quality is in many places poor due to several different causes, among these oil palm cultivation and palm oil processing (Afroz and Rahman, 2017; Badan Pusat Statistik, 2018). Palm oil used for the production of biofuels consumed in the EU which adheres to the RED sustainability criteria will have avoided some of the most severe water quality impacts from oil palm cultivation and processing. Notably, soil erosion & ensuing siltation in waterways is a commonly observed and quite detrimental consequence of conversion of natural forests to oil palm plantations. Given the ban in the RED on use of palm oil from recently converted forests, this particular factor should be alleviated, especially as soil erosion tends to diminish as plantations mature (Dislich et al., 2017). At the same time, waterways adjacent to mature plantations have been shown to have distinctly higher sediment levels, though less so than in recently established plantations. Similarly, water temperatures in plantation-adjacent streams are significantly higher than in forest streams although here as well, the difference is somewhat smaller in mature plantations (Carlson et al., 2014).

In terms of water quality impacts from emissions of palm oil mill effluent (POME), this remains a problematic issue. In the oil mill, POME goes through different treatment stages before being discharged to waterways, but this treatment may not suffice to bring down levels of oxygen down to the levels prescribed in environmental legislation

(Bello and Abdul Raman, 2017; Liew et al., 2015). In Malaysia, many - though likely not all[167] - industries are able to meet current BOD emission standards of 100 mg/l (Bello and Abdul Raman, 2017; Loh et al., 2017). Mills in Malaysian Borneo have to meet even stricter standards of 20 mg/l, which is in the process of becoming the nation-wide standard as well (Tabassum et al., 2015). For this reason, much research effort is currently being put into development of technologies to meet the tougher standards (Bello and Abdul Raman, 2017). According to Paramitadevi & Rahmatullah (2017) most oil mills in Indonesia do not comply with discharge limits even though these are less strict than in Malaysia. See Table 26 for an overview of discharge limits in Malaysia and Indonesia.

Table 26. Limits on COD and BOD levels on POME in Malaysia and Indonesia (Iskandar et al., 2018).

	Malaysia	Indonesia
COD (mg/l)	50	350
BOD (mg/l)	100 (20 in Sabah & Sarawak)	100

Soil

Findings from previous Progress Reports

The *2011 biofuels baseline report* notes that soil quality decline is prevalent in oil palm cultivation in Indonesia. Land use change from primary forest to oil palm plantations can result in substantial soil organic carbon losses (especially on peatlands) and has also negative effects on soil stability, leading to erosion and increased risks of landslides. The situation in Malaysia is reported to be largely similar.

The 2012 Renewable Energy Progress and Biofuels Sustainability report adds several other problematic aspects pertaining to palm oil and soil quality. Risks are deemed to be high in all regions for the impact categories contamination, organic matter loss and biodiversity. Risks of erosion are classified as high in Malaysia but not in Indonesia and risks of soil compaction are low in Indonesia and medium in Malaysia. They emphasize in particular, deforestation and excessive leaching as key stressors and note that most soil quality problems in both Malaysia and Indonesia are related to land use change and the early phase of plantation establishment. There are also acid sulphate soils in parts of both countries and these can cause water quality problems if disturbed.

The 2014 Renewable Energy Progress and Biofuels Sustainability report highlights the risks of soil erosion when soils are bare during the establishment phase but note that these risks can be partially mitigated by the use of cover crops. In addition, the fact that the toxic pesticide paraquat binds to soil particles which can cause problems of soil contamination.

The only indicator used for soil quality impacts in non-EU countries by the 2016 Report on Renewable Energy (Oeko-Institut, 2017) is the extent to which crops are being established on soils that are suitable for agriculture.

[167] We have been unable to find more precise data on the percentage of the palm oil mills that meet current and future standards.

Table 27 below summarizes key impacts on soil quality from palm oil, as identified by the previous Progress Reports.

Table 27. Key impacts on soil quality from oil palm cultivation and processing as identified in previous Renewable Energy Progress Reports.

Phase	*Establishment/land use change*	*Agricultural operation*	*Processing*
Impact	Soil erosion, SOC losses	Agrochemicals, esp. pesticides	

Our assessment

An important aspect to be aware of in the assessment of local environmental impacts is that interconnections between soil and water aspects are many and difficult to separate. Notably, soil problems can often be a cause of water problems. As was reviewed in the above discussion on water impacts from oil palm cultivation, soil erosion can transport sediment to adjacent waterways and cause different forms of water quality problems. Another such aspect is how soil compaction in oil palm plantation can increase risks both of floods and droughts. If soils are too compact, water cannot infiltrate and rain is lost as runoff instead of being accumulated and stored in the soil (Dislich et al., 2017).

Soil organic carbon (SOC) losses entail a substantial threat to soil quality, and even though our analysis puts focus not on the conversion from forests to plantation, SOC losses are observed throughout plantation lifespans. This commonly takes place in the form of soil erosion in heavy rains. However, a problem with analysis of soil carbon in oil palm plantations is that there are large variations within as well between plantations. Soil carbon loss is highest in the years immediately following conversion from forests, but SOC levels tend generally to continue to decrease over time, including in mature plantations (Gharibreza et al., 2013). The reason is that there are losses from erosion but there is very little input of carbon. This is in contrast to e.g. rubber plantations wherein leaf litter replenishes the soil (Guillaume et al., 2016). However, if organic matter is added to the soil in the form of e.g. empty fruit bunches and palm fronds, this is likely to alleviate SOC losses (Pauli et al., 2014; Tao et al., 2018). In terms of pesticides and their impact on soil quality, this is an emerging debate in research on the impact of tropical agriculture on ecosystems, and one where there are plenty of research gaps (Costantini, 2015). In terms of oil palm, there is a general lack of studies on both how pesticides are used and if/how they affect soils (Halimah et al., 2016; Ismail et al., 2017; Maznah et al., 2018).

Air

Findings from previous Progress Reports

In terms of air quality impacts of oil palm cultivation, the *2011 biofuels baseline report* emphasize especially haze from the use of fire as land preparation, in both Indonesia and Malaysia. The seriousness of this issue is raised also by the 2012 Renewable Energy Progress and Biofuels Sustainability report, which also highlights potential risks from agrochemical application (especially for workers) and emissions from processing in the form of soot and dust. The haze from burning is raised also in the 2014 Renewable Energy Progress and Biofuels Sustainability report, which however points out that it is uncertain to which extent fires in Indonesia can be attributed to oil palm plantations. The 2016 Report on Renewable Energy (Oeko-Institut, 2017) does not discuss air quality impacts.

Table 28 below summarizes key impacts on air quality from palm oil, as identified by the previous Progress Reports.

Table 28. Key impacts on air quality from oil palm cultivation and processing as identified in previous Renewable Energy Progress Reports.

Phase	*Establishment/land use change*	*Agricultural operation*	*Processing*
Impact	Burning -> haze	Agrochemicals, esp. pesticides	Soot from boiler

Our assessment

Adherence to the sustainability criteria in the RED and the ensuing fact that all palm oil used for biofuels in the EU is certified, should mitigate the worst air quality problem pertaining to oil palm cultivation, namely the haze from the use of fire as land preparation. However, results from a recent study (Carlson et al., 2018) indicate that although certification has reduced deforestation, it did not reduce the prevalence of fires in certified plantations. It is often impossible to determine exactly where a fire has originated without careful onsite inspection, which means that attributing air quality impacts from fire to any specific plantation is very difficult (Gaveau et al., 2017).

In terms of processing emissions, POME is not only a water quality problem but an air quality issue as well, because the open ponding system commonly employed as part of the treatment process emit a very strong odor. However, methane capture systems - mandatory for palm oil processed for EU biofuel purposes – reduce the smell significantly (Moriarty et al., 2014). Palm oil mills combust residues to generate process heat and sometimes electricity. This has been pointed out as an air quality problem in previous Progress Reports, and there are reports of substantial particulate emissions, but there is a lack of knowledge on the prevalence and extent of these emissions (Chong et al., 2014; Hanafi et al., 2016).

Biodiversity

Findings from previous Progress Reports

The *2011 biofuels baseline report* carries out a mapping of monitoring and governance systems in different countries supplying biofuels to the EU and classify each country accordingly. In terms of methodology, the baseline study identifies a set of indicators by which impacts on biodiversity can be assessed. These include quantitative indicators pertaining to land use change (from natural ecosystems to croplands) as well as whether or not the specific country is a signatory of the Convention on Biological Diversity (CBD). The study finds that Malaysia is a “medium” risk country in terms of presence and potential of enforcement pertaining to biodiversity monitor and governance mechanisms, and Indonesia is classified as “low” risk. However, in terms of actual impacts on, and threats to, biodiversity in Indonesia, the report raises serious concerns about biodiversity threats especially from land use change. The threat is particularly severe when primary forest is converted to oil palm plantations, as this may result in very large levels of biodiversity loss. Conversion to oil palm from other forms of plantations – such as rubber –

does not have the same destructive change however. As for Malaysia, the report notes that oil palm expansion has been the main driver of deforestation and that this has led to a very high extent of biodiversity loss.

The 2012 Renewable Energy Progress and Biofuels Sustainability report also uses loss of natural ecosystems as a proxy for biodiversity loss but notes that the risks of biodiversity loss connected to EU biofuels were “low” in Indonesia and “medium” in Malaysia. The 2014 Renewable Energy Progress and Biofuels Sustainability report deems biodiversity risks pertaining to oil palm cultivation in Indonesia and Malaysia to be “high (medium confidence)”. They note that there is substantial land use change from natural ecosystems to oil palm plantations in highly biodiverse regions such as Sumatra and Borneo. However, the impact of EU biofuel demand will only be indirect, as biofuel sourced from feedstock grown on recently deforested lands are not allowed according to the 2009 Renewable Energy Directive.

The 2016 Report on Renewable Energy (Oeko-Institut, 2017) also touches upon the fact that many direct risks to biodiversity are avoided as a result of the RED sustainability criteria that exclude many of the negative biodiversity impacts pertaining to land use change. It is however noted here as well that there are significant risks of indirect (displacement) negative effects on biodiversity in Indonesia and Malaysia.

Table 29 below summarizes key impacts on biodiversity from palm oil, as identified by the previous Progress Reports.

Table 29. Key impacts on biodiversity from oil palm cultivation and processing as identified in previous Renewable Energy Progress Reports.

Phase	*Establishment/land use change*	*Agricultural operation*	*Processing*
Impact	Destruction of very biodiverse habitats	Pest management	

Our assessment

As noted above, adherence to the RED sustainability criteria and the fact that palm oil used for EU biofuels is certified should exclude many of the negative effects in biodiversity that come from conversion of natural forests to oil palm plantation. Certificates do not necessarily cover the biodiversity impacts from the cultivation activities, although the most common certificates for palm oil (RSPO and ISCC) do. Still, some biodiversity impacts are difficult to avoid. For instance, impacts in the form of damaged air, soil and water quality come with follow-on effects on biodiversity. Conversely, measures that mitigate negative impacts on air, soil & water tend to correlate with improvements in biodiversity. For example, application of empty fruit bunches to the soil was noted above as effective in hindering soil organic carbon losses but also has a positive effect on soil biodiversity. However, actual practices for application of oil palm residues can determine their effectiveness in improving biodiversity. For example, application in distinct piles is less effective than even distribution (Tao et al., 2018; Wong et al., 2016). Similarly, sediment deposition in adjacent waterways have detrimental effects on aquatic biodiversity (Harun et al., 2015). Oil palm plantations have been shown to have negative effects on biodiversity outside of the specific plantation itself, with species richness in adjacent natural forests being decreasing with increased proximity to the plantation (Scriven et al., 2018). Methods for plantation establishment and implementation of different management practices can sometimes be effective in retaining certain levels of biodiversity in plantations. For example, forested riparian reserves have been shown to help maintain aquatic biodiversity in waterbodies close to oil palm plantations. Reserves (buffer zones) reduce sediment deposition from soil erosion and also provide leaf litter input (Giam et al., 2015). In conclusion, there is a growing body of knowledge on the impacts on biodiversity from different choices in terms of management practices. However, there are thus far few indications that point towards reduced pressure on biodiversity from oil palm expansion in Indonesia and Malaysia (Meijaard et al., 2018).

C.4 Soybean (Brazil)

Brazilian soybean cultivation has experienced a very strong increase in recent decades. Since 2010, annual production of soybean in Brazil has grown by more than 60%. Exports have more than doubled, with more than 75% of exports going to China in 2016/2017. Although soybeans are mostly used for different forms of animal feed, soybean oil is also used as a raw material for biodiesel production. Brazilian soybean oil demand is increasingly being driven by a growing domestic market for biodiesel, resulting from new and higher mandates for biodiesel blending (USDA FAS, 2018b).

Historically as well as currently, demand for soybean meal has however been the main driver of demand for soybean as such and the oil has been more of a secondary product. This makes it somewhat complicated to determine how much of the environmental impacts should be attributed specifically to the oil (Bailis, 2014). Lima et al (2011) estimated that about 20% of deforestation in the Mato Grosso province could be attributed to soybean expansion (with about 80% attributed to cattle grazing) and 1-3% to biodiesel demand, although this will vary depending on current market demand for meal and oil, respectively. Whereas 20% of the soybean mass is oil, the oil share of revenue from can vary depending on relative market prices of meal and oil. For example, Castanheira et al (2015) use a range of 35-44% for the share of revenue coming from the sales of soybean oil, based on market prices in the time period 2009-2013.

In terms of environmental impacts, much focus has been on soybean expansion as a cause of deforestation in the Brazilian Amazon. However, the recent decade has seen significant reductions in deforestation rates in the Amazon, due at least partly to consumer-induced corporate action aimed at eliminating Amazon deforestation from supply chains. However, to the South-East of the Amazon lies the Cerrado, a vast biome with highly biodiverse forest and savannah ecosystems where soybean cultivation is expanding faster than anywhere else. While deforestation is decreasing in the Amazon, land use change and associated losses of highly important ecosystem services continues in the Cerrado. Given a) the growing pressure on the Cerrado and b) that Member States source soybean from regions there that are at risk of deforestation (TRASE, 2018), our assessment herein will have a particular focus on the Cerrado.

Water

Findings from previous Progress Reports

The *2011 biofuels baseline report* notes that there are issues pertaining to water pollution resulting from soybean cultivation in Brazil but does not go into more detail as to how these are manifest. It is however noted that weed resistance to the pesticide glyphosate has led to increased use of other more toxic pesticides. The 2012 Renewable

Energy Progress and Biofuels Sustainability report does a closer analysis of water impacts in Brazil only pertaining to sugar cane cultivation, not soybean. The 2014 Renewable Energy Progress and Biofuels Sustainability report highlights the growing toxicity of pesticides used as a potential water quality risk. The 2016 Report on Renewable Energy (Oeko-Institut, 2017) does not do a specific analysis of water quality impacts pertaining to cultivation of soybeans in Brazil.

Our assessment

While the Amazon basin holds the vast majority of Brazil's water resources, it is located far away from Brazil's more densely populated regions. The Cerrado holds less water in terms of absolute volumes, but the headwaters of three large river systems are found in the Cerrado which means that it is highly important for Brazilian freshwater supply (Dickie et al., 2016). The continuing expansion in the Cerrado of agriculture in general and soybean cultivation in particular has been pointed out as a significant risk factor pertaining to (especially long-term) effects on water resources. Decreased evapotranspiration in cultivated lands - compared to native Cerrado – runs the risk of creating shifts in regional weather patterns (Spera et al., 2016) with potentially detrimental effects on both agricultural conditions in the Cerrado and the Amazon, as well as on water supply for Brazilian cities. Increased use of "double-cropping" (see soil section for details) has however the potential to alleviate some of these effects (ib).

In addition to the effects on water cycles and water volumes, increased agricultural activity in the Cerrado has been accompanied by an increase in the use of agrochemicals in the form of fertilizer and pesticides. As is noted in the previous Progress Reports, this is a risk factor when it comes to water quality in waterways close to fields. Soybean is a nitrogen-fixating crop which is rarely fertilized with nitrogen. However, soybeans are cultivated in crop rotation schemes together with crops that do require application of nitrogen fertilizer (e.g. cotton or maize), which can explain increased nitrogen levels as well as eutrophication in waterways adjacent to fields used to grow soybean (Hunke et al., 2015a; Neill et al., 2017).

Neill et al (2017) argue however that on the whole, water quality impacts from agricultural expansion in the Cerrado have been rather limited, at least when it comes to effects from nutrients. This is attributed to relatively low rates of erosion and the high capacity of Cerrado soils to fixate phosphorus. Neill et al (2017) also point to the fact the soils are rather permeable, which reduces surface runoff, although it should be mentioned that Hunke et al (2015a) emphasize the significant difference in soil permeability between natural Cerrado soils and those that are under pasture or crop cultivation. Also, Merten et al (2015) argue that while no-tillage systems are effective in reducing soil loss, they are less so when it comes to controlling surface runoff.

When it comes to impacts on Cerrado water quality from pesticides, this is an issue where there are substantial potential risks but also large uncertainties pertaining to site-specificity. No-tillage systems should reduce the risk of surface runoff of pesticides and other agrochemicals, but as Merten et al (2015) notes, this effect may be overstated. Pesticides are routinely found in both surface water and ground waters in the Cerrado. Observed concentrations often exceed EU limits and sometimes also those set in Brazilian legislation, even though the latter tend to be laxer. Among the pesticides found are carbofuran and atrazine, two substances that are banned for use in agriculture in the EU. However, these are all point measurements and as emphasized however, it is not straightforward that these can be extrapolated and interpreted as indicative for the Cerrado in general (Hunke et al., 2015a).

Soil

Findings from previous Progress Reports

The *2011 biofuels baseline report* notes that soil erosion can be a problem with soybean cultivation, although this problem is largely mitigated in cultivation systems based on no-till farming. These are dominant in Brazil as well as Argentina. The 2012 Renewable Energy Progress and Biofuels Sustainability report discusses soil quality aspects pertaining to cultivation of biofuel feedstock based on a set of different indicators, see Table 30.

Table 30. Soil quality characteristics of different regions in Brazil, according to the 2012 Renewable Energy Progress and Biofuels Sustainability report.

Region	Erosion	Compaction	Contamination	SOC loss	Biodiversity loss
West-Central/South	Low	Medium	High	Medium	High
Northeast	Medium	High	High	High	High

The 2012 Renewable Energy Progress and Biofuels Sustainability report also highlights that expansion of soybean cultivation in the Brazilian Cerrado entails a risk as Cerrado soils are acidic and low in fertility. The 2014 Renewable Energy Progress and Biofuels Sustainability report emphasizes the risk of soil erosion from the widespread use of no-till systems used for soybean cultivation in Brazil. At the same time, increased use of toxic pesticides (because of weed resistance to glyphosate, otherwise the dominant pesticide) is leading to higher risks of soil contamination. The 2016 Report on Renewable Energy (Oeko-Institut, 2017) notes that the vast majority of expansion of soybean cultivation in Brazil in the time period 2007-2014 was onto area that is suitable of very suitable for crop cultivation.

Our assessment

In their natural state, Cerrado soils have high carbon content in their upper layers (de Sant-Anna et al., 2017) but are not very suitable for agriculture, as they are acidic with low nutrient availability. For this reason, crop cultivation in the Cerrado only became possible as a result of large-scale application of lime to increase soil pH and the introduction of more hardy genetically modified crop cultivars (Hunke et al., 2015a; Trabaquini et al., 2017).

As in the rest of South America, soybean cultivation in Brazil, including the Cerrado, is predominantly based on no-tillage systems. While conversion of natural forest to agriculture entails substantial changes in terms of decreased soil organic matter (SOM) levels and increased risks of soil erosion (Corbeels et al., 2016; Stefanoski et al., 2016), implementation of no-tillage can alleviate these issues. Increased SOM levels are found in fields cultivated under conventional tillage are converted to no-tillage, although the increase flattens out after some years when soils have reached a new “steady-state” pertaining to soil carbon content (Corbeels et al., 2016; de Sant-Anna et al., 2017). No-tillage has been implemented in the Cerrado since the 1980s (Corbeels et al., 2016) but this seems not to have fully sufficed when it comes to controlling soil erosion (Hunke et al., 2015a). One factor that has been identified is the intensification of cultivation processes that began in the early 2000s with the introduction of faster growing soybean cultivars. This enabled “double-cropping” whereby cultivation of soybean in a field is directly followed by cotton or maize, in effect making it possible to grow two crops within one growing season (Corbeels et al., 2016;

Spera et al., 2016). A consequence of this is that the use of cover crops has decreased and that conventional tillage (used for the non-soybean crops) has increased (Hunke et al., 2015b).

As for the impact of pesticides, the application of insecticides is particularly important when it comes to soybean. This is primarily due to the fact that the substances are particularly toxic for aquatic biota (Hunt et al., 2016). While it is clear that the use of pesticides has increased substantially with agricultural expansion in the Cerrado, their environmental effects are uncertain (Hunke et al., 2015b). As is highlighted by for example Castanheira et al (2015), there is a lack of methods that can be used to model pesticide emissions and effects, because actual impacts can vary greatly depending on exact substance used as well as site-specific contexts. Regardless, when it comes to preventing these forms of contaminations, improved implementation of riparian buffer strips is seen as key (Hunt et al. 2016).

Air

Findings from previous progress reports

The *2011 biofuels baseline report* does not specify any particular risks pertaining to air quality for soybeans cultivated in Brazil, but the 2012 Renewable Energy Progress and Biofuels Sustainability report identifies Brazilian soybean as a high-risk crop for air quality attributed to a prevalence of burning of crop residues as a means of field preparation. The 2014 Renewable Energy Progress and Biofuels Sustainability report also identifies residue burning and possible pesticide drift-off as potential risks pertaining to Brazilian soybean cultivation, whereas the 2016 Report on Renewable Energy (Oeko-Institut, 2017) does not do a specific analysis of air quality impacts pertaining to cultivation of soybeans in Brazil.

Our assessment

The previous progress reports identified agricultural burning and pesticide drift-off as the most important air quality factors when it comes to soybean in Brazil. Burning is used in different stages of the land preparation process. First of all during the deforestation phase - as an efficient means of land clearing - and in the actual agricultural operation phase, where fire can serve a range of different purposes, including pest control, nutrient mobilization and removal of residues (Cano-Crespo et al., 2015). Conversion from natural land use (forest or savanna) to pastures is the most important direct driver of deforestation in Brazil, but a second step is often that the pastures are converted to crop cultivation. In this latter process, burning of the pasture is also a commonplace process (Figueira et al., 2016).

As was noted in in the introduction to this Section C4, the recent decade has seen a significant decline in deforestation rates in the Brazilian Amazon. The strong connection between deforestation and fires has meant that with reduced deforestation, the occurrence of fires has gone down as well with substantial effects in terms of air quality. Given the detrimental health effects of air pollution from forest fires, especially particulate emissions, less burning also has clear health effects. Reddington et al (2015) estimate that the reduced prevalence of fire has led to 400-1700 fewer premature adult deaths in South America.

The role of fire in deforestation and the air quality issues associated with agricultural burning have led to the introduction of fire suppression policies in Brazil. However, some argue that the urge to reduce fire has gone too far, especially in the context of the Cerrado. Like other savannas, the Cerrado is very fire-prone during the dry season and hence fires are a natural component of the ecosystem. Hence, overzealous suppression of fires can have seriously negative effects on biodiversity (Cava et al., 2018; Durigan and Ratter, 2016).

Biodiversity

Findings from previous progress reports

The *2011 biofuels baseline report* notes that expansion of soybean cultivation in Brazil can be a potential risk in terms of at least indirectly driving deforestation, with ensuing risks pertaining to loss of biodiverse habitats. The 2012 Renewable Energy Progress and Biofuels Sustainability report highlights that soybean is a driver of the expansion of the Brazilian agricultural frontier in natural ecosystems, especially savannahs and shrublands. The 2014 Renewable Energy Progress and Biofuels Sustainability report describes how several biomes in Brazil – the most biodiverse country in the world – are affected by expansion of soybean cultivation. EU soy imports come especially from the Amazon and Cerrado biomes, which are under threat of deforestation and conversion to cropland. The report however emphasizes the effectiveness of the 2006 moratorium on soy expansion in the Amazon in holding back deforestation in the region. The 2016 Report on Renewable Energy (Oeko-Institut, 2017) classifies Brazil as a “medium risk” country in terms of biodiversity loss from production of biofuel feedstock.

Our assessment

After the signing of the 2006 Soy Moratorium, wherein major buyers of soybeans committed to not purchase soy grown on land that had been deforested after mid-2006, forest loss in the Amazon has decreased substantially (Gibbs et al., 2015; Kastens et al., 2017). Regardless of how much of this reduction is due to the moratorium and how much is due to other factors (Godar et al., 2014; Nepstad et al., 2014), one significant limitation of the moratorium is that it only applies to the Amazon biome. The Cerrado is not included in the Soy Moratorium and only half of all soybeans exported from the Cerrado are covered by Zero-Deforestation Commitments (TRASE, 2018).

The largest threat to biodiversity in the Cerrado is arguably the continuing pattern of conversion of land from forest and savanna to agriculture in the form of pastures or crop cultivation. In the introduction to this section we noted that the Brazilian Cerrado is classified as one of the earth’s biodiversity hotspots, an indication of the species richness that it hosts. Among the species that inhabit the Cerrado, about 4800 species are endemic. If current patterns of land use change in the Cerrado continue, 10% of these endemic species will likely be extinct by 2050 (Strassburg et al., 2017).

There are initiatives that aim to follow the model of the Soy Moratorium by getting large buyers to pledge not to buy soybean from recently deforested lands in the Cerrado. Many large restaurants and retailers have signed on to a so-called Cerrado Manifesto but it is believed that this will not be effective until the large commodity firms are fully onboard as well (Belmaker, 2018; Gross, 2018).

In addition to the biodiversity risks associated with land use change, management aspects can also play a role. In these cases, there are often interconnections with other environmental aspects that we have reviewed herein. For example, the section on water quality highlighted the importance of proper buffer strips along waterways so as to reduce risks of agrochemical contamination of streams. Another important aspect in the Cerrado that was discussed in section on air quality is the tension pertaining to the role of fire both as an air quality problem and an important process in maintaining and restoring biodiversity in savanna ecosystems.

C.5 Maize (Ukraine)

Background

As has been the case in other eastern and central European countries (Brinkman et al., 2017), Ukrainian agriculture has seen decades of substantial changes following the breakdown of the Soviet Union in the early 1990s. The transition towards a market economy and the ensuing liberalization of agriculture entailed a massive change in terms of exposure to international competition and removal of price controls on various inputs. Drastic changes followed in the form of completely rearranged ownership structures, as well as farm abandonment and urban migration (Baumann et al., 2011).

Despite the political turmoil in Ukraine in recent years, the country's large grain production and export has stayed relatively stable. The country is one of the world's largest producers of grains, as well as one of the largest export countries. The expansion has been driven by a strong international market as well as systemic advantages pertaining to the role of corn in crop rotation schemes used by Ukrainian farmers. In 2017/18, more than 70% of Ukrainian corn was exported, with half of exports destined for the European Union and with Spain, the Netherlands and Portugal as the largest importers among the EU Member States (USDA FAS, 2018c).

Spain and the Netherlands are also the most important countries in terms of EU production of bioethanol based on maize imported from Ukraine. One reason for the preference for Ukrainian maize is that it is not based on genetically modified (GM) seeds, which makes the by-products from ethanol production more attractive on the EU market for animal feed (USDA FAS, 2018a).

Water

Findings from previous progress reports

The *2011 biofuels baseline report* analyses the situation in Ukraine, but only pertaining to cultivation of sugar beet and rapeseed.

Our assessment

The transformative changes to Ukrainian society following the collapse of the Soviet Union had a clear effect on the interrelationship between water and agriculture. Agricultural water withdrawal decreased substantially with shrinking production with a 75% reduction in irrigation (OECD, 2015). Although grain crops like maize are primarily rainfed, there are ongoing discussions on the potential to achieve large yield increases in the southeastern part of Ukraine by increased use of irrigation on maize, wheat and alfalfa (Bleyzer Foundation, 2016). There are however question marks as to whether it is realistic to expect these ambitions to be fulfilled (Deppermann et al., 2018).

There were also notable water quality effects. The drastic reduction in livestock production entailed a corresponding drop in nutrient export to Ukrainian waterways, which led to a marked improvement of the water quality in several rivers (Tavares Wahren et al., 2012). Livestock numbers in Ukraine are still very low compared to pre-1990 levels, but grain production has experienced a significant recovery, which has increased the nutrient loads coming from croplands. Another factor contributing to this are shortcomings when it comes to implementation of policy measures pertaining to buffer zones between croplands and waterways (Hagemann et al., 2014).

Soil

Findings from previous progress reports

The 2016 Report on Renewable Energy (Oeko-Institut, 2017) notes that in general, cereal crops (including maize/corn) is predominantly planted on soils with a low suitability for crop production. More recent (2008-2014) expansion of cropland has however taken place onto more suitable lands than what was already in place pre-2008.

Our assessment

A majority of the soils in Ukraine are so-called Chernozems, historically considered among the highest quality soils in the world. Their characteristics in terms of structure, humus content and bulk density make them very suitable for crop cultivation (Jones et al., 2012). At the same time, these soils are quite vulnerable to mismanagement. Assessments of long-term soil quality development in Ukraine have found negative developments in several different key characteristics, with erosion, soil carbon content losses and soil compaction being particularly prevalent (Pennock et al., 2015, pp. 350–353).

Although there is a lack of consistent data on long-term trends in terms of soil quality in Ukraine, large swaths of land are covered with soils that are degraded in one way or another. Erosion from wind and water have negative effects on up to 20% of the country's land area and there are not sufficient policy measures in place to incentivize the soil protection measures needed to hinder continued degradation (Stupak, 2016). The first decades of the 2000s have seen improvements in the form of growing implementation of minimum tillage practices, but more measures need to be implemented so as to accumulate soil organic carbon, improve soil structure and thereby make soils less amenable to erosion (Fileccia et al., 2014).

Air

Findings from previous progress reports

Air quality aspects pertaining to cultivation of maize in Ukraine are not covered in any of the previous renewable energy progress reports.

Our assessment

As was noted in section on soil quality, erosion is a well-recognized and serious problem in Ukraine, and one that has effects well beyond soil as such and well beyond Ukraine. Dust from dry Ukrainian lands has been the source of air pollution problems in locations as far away as the UK (Bessagnet et al., 2008; Birmili et al., 2008). Alleviating problems of wind erosion in Ukraine is thus a matter not only of the long-term conditions for Ukrainian agriculture but of air quality all over Europe. Improved soil management through conservation tillage and reducing wind speeds through the establishment and maintenance of shelterbelts are key tools to address this problem (Chornyy and Volosheniuk, 2016; Stupak, 2016).

Biodiversity

Findings from previous progress reports

Biodiversity aspects pertaining to cultivation of maize in Ukraine is not covered in any of the previous renewable energy progress reports.

Our assessment

The drastic structural changes in the early 1990s to the agricultural sector in the former USSR brought about an immense abandonment of large swaths of farmland. The vast political and socio-economical aspects of this transition notwithstanding, the land abandonment appears to have been quite positive for biodiversity in parts of the Eurasian steppe zones of the former Soviet Union, especially in the case of grassland birds (Kamp et al., 2011). However, most abandonment in Ukraine took place outside the steppe indicating that this issue might be less relevant for our particular case (Baumann et al., 2011; Kamp et al., 2011).

However, the potential gains from reclaiming abandoned farmland have in recent years precipitated a discussion in the research community on the magnitude and effects of this process. This is important beyond this particular region, because expansion of crop cultivation in Ukraine and other parts of the Chernozem belt could be one component among others to relieve pressures on agricultural frontiers in parts of the world (Schierhorn et al., 2013), especially highly biodiverse regions in the tropics (Kamp et al., 2015; Meyfroidt et al., 2016). In addition to expansion of the agricultural area in Ukraine and its neighbours, there are large potential gains to be made from intensification land already under cultivation. There is a substantial yield gap between current production levels and what would be possible given improved management, which if alleviated could entail large increases in Ukrainian grain production volumes (Deppermann et al., 2018).

The grasslands of the Eurasian steppe - that are in some sense the “natural” landscapes in Ukraine - are not only home to many bird species (Kamp et al., 2015); they also hold much biodiversity pertaining to vascular plants, bryophytes and lichens (Kuzemko et al., 2016). However, given that steppe can easily be converted to farmland and that the soils are very suitable for crop cultivation, vast areas of the Eurasian steppe is now used for agriculture and only small fractions of the steppe remain intact. The remaining patches of steppe are found partly in protected areas, but also in agricultural regions in spots that for some reason are unsuitable for agriculture such as very steep slopes or on grass-covered burial mounds, so-called *kurgan* (Dembicz et al., 2016). Even though these small remaining parts of the steppe only make up about one percent of the Ukrainian land area, they are vital habitats for almost a third of the red-listed species in the country (Kuzemko et al., 2016). These patches are often not directly areas suitable for agriculture, but they could impact the buffer zones currently set up around these patches.

C.6 References

Afroz, R., Rahman, A., 2017. Health impact of river water pollution in Malaysia. International Journal of Advanced and Applied Sciences 4, 78–85. https://doi.org/10.21833/ijaas.2017.05.014

Almaraz, M., Bai, E., Wang, C., Trousdell, J., Conley, S., Faloona, I., Houlton, B.Z., 2018. Agriculture is a major source of NOx pollution in California. Science Advances 4, eaao3477. https://doi.org/10.1126/sciadv.aao3477

Badan Pusat Statistik, 2018. Statistical yearbook of Indonesia 2017. Badan Pusat Statistik, Jakarta.

Bailis, R., 2014. Brazil: Biodiesel, in: Solomon, B.D., Bailis, R. (Eds.), Sustainable Development of Biofuels in Latin America and the Caribbean. Springer New York, New York, NY, pp. 103–126. https://doi.org/10.1007/978-1-4614-9275-7_4

Baumann, M., Kuemmerle, T., Elbakidze, M., Ozdogan, M., Radeloff, V.C., Keuler, N.S., Prishchepov, A.V., Kruhlov, I., Hostert, P., 2011. Patterns and drivers of post-socialist farmland abandonment in Western Ukraine. Land Use Policy 28, 552–562. https://doi.org/10.1016/j.landusepol.2010.11.003

Bello, M.M., Abdul Raman, A.A., 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. https://doi.org/10.1016/j.jenvman.2017.04.050

Belmaker, G., 2018. More companies sign on to Cerrado Manifesto [WWW Document]. Mongabay. URL https://news.mongabay.com/2018/08/more-companies-sign-on-to-cerrado-manifesto/ (accessed 9.8.18).

Berger, M., Pfister, S., Bach, V., Finkbeiner, M., Berger, M., Pfister, S., Bach, V., Finkbeiner, M., 2015. Saving the Planet's Climate or Water Resources? The Trade-Off between Carbon and Water Footprints of European Biofuels. Sustainability 7, 6665–6683. https://doi.org/10.3390/su7066665

Bessagnet, B., Menut, L., Aymoz, G., Chepfer, H., Vautard, R., 2008. Modeling dust emissions and transport within Europe: The Ukraine March 2007 event. Journal of Geophysical Research: Atmospheres 113. https://doi.org/10.1029/2007JD009541

Birmili, W., Schepanski, K., Ansmann, A., Spindler, G., Tegen, I., Wehner, B., Nowak, A., Reimer, E., Mattis, I., Müller, K., 2008. A case of extreme particulate matter concentrations over Central Europe caused by dust emitted over the southern Ukraine. Atmospheric Chemistry and Physics 8, 997–1016.

Bleyzer Foundation, 2016. Unleashing Ukrainian Agricultural Potential To Improve Global Food Security.

Borrelli, P., Lugato, E., Montanarella, L., Panagos, P., 2017. A New Assessment of Soil Loss Due to Wind Erosion in European Agricultural Soils Using a Quantitative Spatially Distributed Modelling Approach. Land Degradation & Development 28, 335–344. https://doi.org/10.1002/ldr.2588

Brinkman, M.L.J., Wicke, B., Faaij, A.P.C., 2017. Low-ILUC-risk ethanol from Hungarian maize. Biomass and Bioenergy 99, 57–68. https://doi.org/10.1016/j.biombioe.2017.02.006

Butler, D., 2018. Scientists hail European ban on bee-harming pesticides [WWW Document]. Nature. https://doi.org/10.1038/d41586-018-04987-4

Cano-Crespo, A., Oliveira, P.J.C., Boit, A., Cardoso, M., Thonicke, K., 2015. Forest edge burning in the Brazilian Amazon promoted by escaping fires from managed pastures. Journal of Geophysical Research: Biogeosciences 120, 2095–2107. https://doi.org/10.1002/2015JG002914

Carlson, K.M., Curran, L.M., Ponette-González, A.G., Ratnasari, D., Ruspita, Lisnawati, N., Purwanto, Y., Brauman, K.A., Raymond, P.A., 2014. Influence of watershed-climate interactions on stream temperature, sediment yield, and metabolism along a land use intensity gradient in Indonesian Borneo. J. Geophys. Res. Biogeosci. 119, 2013JG002516. https://doi.org/10.1002/2013JG002516

Carlson, K.M., Heilmayr, R., Gibbs, H.K., Noojipady, P., Burns, D.N., Morton, D.C., Walker, N.F., Paoli, G.D., Kremen, C., 2018. Effect of oil palm sustainability certification on deforestation and fire in Indonesia. PNAS 115, 121–126. https://doi.org/10.1073/pnas.1704728114

Castanheira, É.G., Grisoli, R., Coelho, S., Anderi da Silva, G., Freire, F., 2015. Life-cycle assessment of soybean-based biodiesel in Europe: comparing grain, oil and biodiesel import from Brazil. Journal of Cleaner Production 102, 188–201. https://doi.org/10.1016/j.jclepro.2015.04.036

Cava, M.G.B., Pilon, N.A.L., Ribeiro, M.C., Durigan, G., 2018. Abandoned pastures cannot spontaneously recover the attributes of old-growth savannas. Journal of Applied Ecology 55, 1164–1172. https://doi.org/10.1111/1365-2664.13046

Chong, W.C., Rashid, M., Ramli, M., Ruwaida, J., Noor, Z.Z., 2014. Effect of Flue Gas Recirculation on Multi-Cyclones Performance in Reducing Particulate Emission from Palm Oil Mill Boiler. Particulate Science and Technology 32, 291–297. https://doi.org/10.1080/02726351.2013.856360

Chornyy, S.G., Volosheniuk, A.V., 2016. Evaluation of wind erosion protective efficiency No-till technology in southern Ukraine steppe conditions. 1 17, 50–63.

Corbeels, M., Marchão, R.L., Neto, M.S., Ferreira, E.G., Madari, B.E., Scopel, E., Brito, O.R., 2016. Evidence of limited carbon sequestration in soils under no-tillage systems in the Cerrado of Brazil. Scientific reports 6, 21450.

Costantini, D., 2015. Land-use changes and agriculture in the tropics: pesticides as an overlooked threat to wildlife. Biodivers Conserv 24, 1837–1839. https://doi.org/10.1007/s10531-015-0878-8

de Sant-Anna, S.A.C., Jantalia, C.P., Sá, J.M., Vilela, L., Marchão, R.L., Alves, B.J.R., Urquiaga, S., Boddey, R.M., 2017. Changes in soil organic carbon during 22 years of pastures, cropping or integrated crop/livestock systems in the Brazilian Cerrado. Nutrient Cycling in Agroecosystems 108, 101–120. https://doi.org/10.1007/s10705-016-9812-z

Dembicz, I., Moysiyenko, I.I., Shaposhnikova, A., Vynokurov, D., Kozub, Ł., Sudnik-Wójcikowska, B., 2016. Isolation and patch size drive specialist plant species density within steppe islands: a case study of kurgans in southern Ukraine. Biodivers Conserv 25, 2289–2307. https://doi.org/10.1007/s10531-016-1077-y

Deppermann, A., Balkovič, J., Bundle, S.-C., Fulvio, F.D., Havlik, P., David Leclère, Lesiv, M., Prishchepov, A.V., Schepaschenko, D., 2018. Increasing crop production in Russia and Ukraine—regional and global impacts from intensification and recultivation. Environ. Res. Lett. 13, 025008. https://doi.org/10.1088/1748-9326/aaa4a4

DG ENV, 2018. Report From The Commission To The Council And The European Parliament. Environment Directorate-General - Environment - European Commission, Brussels, Belgium.

DG Health and Food Safety, 2017. Overview Report: Sustainable Use of Pesticides.

Dickie, A., Magno, I., Giampetro, J., Dolginow, A., 2016. Challenges And Opportunities For Conservation, Agricultural Production, And Social Inclusion In The Cerrado Biome. Climate and Land Use Alliance.

Dislich, C., Keyel, A.C., Salecker, J., Kisel, Y., Meyer, K.M., Auliya, M., Barnes, A.D., Corre, M.D., Darras, K., Faust, H., Hess, B., Klasen, S., Knohl, A., Kreft, H., Meijide, A., Nurdiansyah, F., Otten, F., Pe'er, G., Steinebach, S., Tarigan, S., Tölle, M.H., Tscharntke, T., Wiegand, K., 2017. A review of the ecosystem functions in oil palm plantations, using forests as a reference system. Biological Reviews 92, 1539–1569. https://doi.org/10.1111/brv.12295

Durigan, G., Ratter, J.A., 2016. The need for a consistent fire policy for Cerrado conservation. Journal of Applied Ecology 53, 11–15. https://doi.org/10.1111/1365-2664.12559

ECA, 2016. The EU system for the certification of sustainable biofuels. Special Report No 18, 2016. (Website). European Court of Auditors.

Ecofys, Agra CEAS, Chalmers University, IIASA, Winrock International, 2011. Biofuels baseline 2008 (No. Tender No. TREN/D1/458/2009).

EEA, 2018. European Waters - Assessment of status and pressures 2018 (No. 7/2018). European Environment Agency.

EEA, 2017. Air quality in Europe — 2017 report (No. 13/2017). European Environment Agency.

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.

Ellis-Petersen, H., 2018. How palm oil ban has made the EU a dirty word in Malaysia. The Guardian.

Eurostat, 2018. Agri-environmental indicator - irrigation.

Eurostat, 2017. Agri-environmental indicator - ammonia emissions.

Figueira, A.M. e S., Davidson, E.A., Nagy, R.C., Riskin, S.H., Martinelli, L.A., 2016. Isotopically constrained soil carbon and nitrogen budgets in a soybean field chronosequence in the Brazilian Amazon region. Journal of Geophysical Research: Biogeosciences 121, 2520–2529. https://doi.org/10.1002/2016JG003470

Fileccia, T., Bernoux, M.M.Y., Guadagni, M., Hovhera, V., 2014. Ukraine: Soil fertility to strengthen climate resilience (No. 91850). The World Bank.

Flach, R., Ran, Y., Godar, J., Karlberg, L., Suavet, C., 2016. Towards more spatially explicit assessments of virtual water flows: linking local water use and scarcity to global demand of Brazilian farming commodities. Environ. Res. Lett. 11, 075003. https://doi.org/10.1088/1748-9326/11/7/075003

Gaveau, D.L.A., Pirard, R., Salim, M.A., Tonoto, P., Husnayaen, Parks, S.A., Carmenta, R., 2017. Overlapping land claims limit the use of satellites to monitor No-Deforestation commitments and No-Burning compliance. Conservation Letters 10. https://doi.org/10.1111/conl.12256

Gharibreza, M., Raj, J.K., Yusoff, I., Othman, Z., Tahir, W.Z.W.M., Ashraf, M.A., 2013. Land use changes and soil redistribution estimation using 137Cs in the tropical Bera Lake catchment, Malaysia. Soil and Tillage Research 131, 1–10. https://doi.org/10.1016/j.still.2013.02.010

Giam, X., Hadiaty, R.K., Tan, H.H., Parenti, L.R., Wowor, D., Sauri, S., Chong, K.Y., Yeo, D.C.J., Wilcove, D.S., 2015. Mitigating the impact of oil-palm monoculture on freshwater fishes in Southeast Asia. Conserv. Biol. 29, 1357–1367. https://doi.org/10.1111/cobi.12483

Gibbs, H.K., Rausch, L., Munger, J., Schelly, I., Morton, D.C., Noojipady, P., Soares-Filho, B., Barreto, P., Micol, L., Walker, N.F., 2015. Brazil's Soy Moratorium. Science 347, 377–378. https://doi.org/10.1126/science.aaa0181

Godar, J., Gardner, T.A., Tizado, E.J., Pacheco, P., 2014. Actor-specific contributions to the deforestation slowdown in the Brazilian Amazon. PNAS 111, 15591–15596. https://doi.org/10.1073/pnas.1322825111

Gross, A.S., 2018. Cerrado Manifesto could curb deforestation, but needs support: experts. Mongabay.

Guillaume, T., Holtkamp, A.M., Damris, M., Brümmer, B., Kuzyakov, Y., 2016. Soil degradation in oil palm and rubber plantations under land resource scarcity. Agriculture, Ecosystems & Environment 232, 110–118. https://doi.org/10.1016/j.agee.2016.07.002

Hagemann, N., Blumensaat, F., Wahren, F.T., Trümper, J., Burmeister, C., Moynihan, R., Scheifhacken, N., 2014. The long road to improving the water quality of the Western Bug River (Ukraine)–A multi-scale analysis. Journal of hydrology 519, 2436–2447.

Halimah, M., Sulaiman, N., Ismail, B.S., Tayeb, M.A., 2016. Dissipation of fluroxypyr in a Malaysian agricultural soil with simulation using the persist and varleach model. Journal of Oil Palm Research 28, 26–33.

Hallmann, C.A., Foppen, R.P.B., Turnhout, C.A.M. van, Kroon, H. de, Jongejans, E., 2014. Declines in insectivorous birds are associated with high neonicotinoid concentrations. Nature 511, 341–343. https://doi.org/10.1038/nature13531

Hallmann, C.A., Sorg, M., Jongejans, E., Siepel, H., Hofland, N., Schwan, H., Stenmans, W., Müller, A., Sumser, H., Hörren, T., Goulson, D., Kroon, H. de, 2017. More than 75 percent decline over 27 years in total flying insect biomass in protected areas. PLOS ONE 12, e0185809. https://doi.org/10.1371/journal.pone.0185809

Hanafi, N.H., Hassim, M.H., Yusuf, M.R.M., 2016. EMISSION FACTOR ESTABLISHMENT FOR PALM OIL MILL BOILER. Jurnal Teknologi 78. https://doi.org/10.11113/jt.v78.9573

Harun, S., Salman Abdo Al-Shami, Ramzah Dambul, Maryati Mohamed, Mohd Harun Abdullah, 2015. Water quality and aquatic insects study at the Lower Kinabatangan River Catchment, Sabah: in response to weak La Niña event. Sains Malaysiana 44, 545–558.

Hunke, P., Mueller, E.N., Schröder, B., Zeilhofer, P., 2015a. The Brazilian Cerrado: assessment of water and soil degradation in catchments under intensive agricultural use. Ecohydrology 8, 1154–1180. https://doi.org/10.1002/eco.1573

Hunke, P., Roller, R., Zeilhofer, P., Schröder, B., Mueller, E.N., 2015b. Soil changes under different land-uses in the Cerrado of Mato Grosso, Brazil. Geoderma Regional 4, 31–43. https://doi.org/10.1016/j.geodrs.2014.12.001

Hunt, L., Bonetto, C., Resh, V.H., Buss, D.F., Fanelli, S., Marrochi, N., Lydy, M.J., 2016. Insecticide concentrations in stream sediments of soy production regions of South America. Sci. Total Environ. 547, 114–124. https://doi.org/10.1016/j.scitotenv.2015.12.140

Immerzeel, D.J., Verweij, P.A., Van Der Hilst, F., Faaij, A.P., 2014. Biodiversity impacts of bioenergy crop production: a state-of-the-art review. Gcb Bioenergy 6, 183–209.

Iskandar, M.J., Baharum, A., Anuar, F.H., Othaman, R., 2018. Palm oil industry in South East Asia and the effluent treatment technology—A review. Environmental Technology & Innovation 9, 169–185. https://doi.org/10.1016/j.eti.2017.11.003

Ismail, B.S., Halimah, M., Tan, Y.A., Tayeb, M.A., 2017. Dissipation of Chlorpyrifos in a Malaysian Agricultural Soil: A Comparison between a Field Experiment and Simulation by the VARLEACH and PERSIST Models. Sains Malaysiana 46, 21–26.

Jerrentrup, J.S., Mitschke, A., Ludwig, J., Dauber, J., Strohbach, M.W., Klimek, S., Mecke, S., 2017. Impact of recent changes in agricultural land use on farmland bird trends. Agriculture, ecosystems & environment.

Jones, A., Panagos, P., Barcelo, S., Bouraoui, F., Bosco, C., Dewitte, O., Gardi, C., Erhard, M., Hervás, J., Hiederer, R., 2012. The State of Soil in Europe.

Kamp, J., Urazaliev, R., Balmford, A., Donald, P.F., Green, R.E., Lamb, A.J., Phalan, B., 2015. Agricultural development and the conservation of avian biodiversity on the Eurasian steppes: a comparison of land-sparing and land-sharing approaches. Journal of Applied Ecology 52, 1578–1587. https://doi.org/10.1111/1365-2664.12527

Kamp, J., Urazaliev, R., Donald, P.F., Hölzel, N., 2011. Post-Soviet agricultural change predicts future declines after recent recovery in Eurasian steppe bird populations. Biological Conservation 144, 2607–2614. https://doi.org/10.1016/j.biocon.2011.07.010

Kastens, J.H., Brown, J.C., Coutinho, A.C., Bishop, C.R., Esquerdo, J.C.D.M., 2017. Soy moratorium impacts on soybean and deforestation dynamics in Mato Grosso, Brazil. PLOS ONE 12, e0176168. https://doi.org/10.1371/journal.pone.0176168

Kemper, L., Partzsch, L., 2018. A water sustainability framework for assessing biofuel certification schemes: Does European hybrid governance ensure sustainability of palm oil from Indonesia? Journal of Cleaner Production 192, 835–843. https://doi.org/10.1016/j.jclepro.2018.05.053

Kuzemko, A.A., Steinbauer, M.J., Becker, T., Didukh, Y.P., Dolnik, C., Jeschke, M., Naqinezhad, A., Uğurlu, E., Vassilev, K., Dengler, J., 2016. Patterns and drivers of phytodiversity in steppe grasslands of Central Podolia (Ukraine). Biodivers Conserv 25, 2233–2250. https://doi.org/10.1007/s10531-016-1060-7

Larsen, R.K., Osbeck, M., Dawkins, E., Tuhkanen, H., Nguyen, H., Nugroho, A., Gardner, T.A., Zulfahm, Wolvekamp, P., 2018. Hybrid governance in agricultural commodity chains: Insights from implementation of ‘No Deforestation, No Peat, No Exploitation’ (NDPE) policies in the oil palm industry. Journal of Cleaner Production 183, 544–554. https://doi.org/10.1016/j.jclepro.2018.02.125

Larsen, R.K., Osbeck, M., Jiwan, N., Rompas, A., Nito, J., Tarigan, A., 2012. Competing Water Claims in Biofuel Feedstock Operations in Central Kalimantan (No. SEI Working Paper 2012-6).

Liew, W.L., Kassim, M.A., Muda, K., Loh, S.K., Affam, A.C., 2015. Conventional methods and emerging wastewater polishing technologies for palm oil mill effluent treatment: A review. Journal of Environmental Management 149, 222–235. https://doi.org/10.1016/j.jenvman.2014.10.016

Lima, M., Skutsch, M., de Medeiros Costa, G., 2011. Deforestation and the social impacts of soy for biodiesel: perspectives of farmers in the South Brazilian Amazon. Ecology and Society 16.

Loh, S.K., Nasrin, A.B., Mohamad Azri, S., Nurul Adela, B., Muzzammil, N., 2017. Biogas Capture–A Means of Reducing Greenhouse Gas Emissions from Palm Oil Mill Effluent. Oil Palm Bulletin 75, 27–36.

Maas, R., Grennfelt, P., 2016. Towards cleaner air. Arctic Monitoring and Assessment Programme.

Maznah, Z., Halimah, M., Ismail, S., Nordiana, A.A., Maznah, Z., Halimah, M., Ismail, S., Nordiana, A.A., 2018. Comparative study on the dissipation of thiram in two type of soils at oil palm (Elaeis guineensis Jacq.) nursery. Chilean journal of agricultural research 78, 86–95. https://doi.org/10.4067/S0718-58392018000100086

Meijaard, E., Garcia-Ulloa, J., Sheil, D., Wich, S.A., Carlson, K.M., Juffe-Bignoli, D., Brooks, T.M., 2018. Oil palm and biodiversity.

Merten, G.H., Araújo, A.G., Biscaia, R.C.M., Barbosa, G.M.C., Conte, O., 2015. No-till surface runoff and soil losses in southern Brazil. Soil and Tillage Research 152, 85–93. https://doi.org/10.1016/j.still.2015.03.014

Meyfroidt, P., Schierhorn, F., Prishchepov, A.V., Müller, D., Kuemmerle, T., 2016. Drivers, constraints and trade-offs associated with recultivating abandoned cropland in Russia, Ukraine and Kazakhstan. Global Environmental Change 37, 1–15. https://doi.org/10.1016/j.gloenvcha.2016.01.003

Michalopoulos, S., 2018. EU Parliament ends palm oil and caps crop-based biofuels at 2017 levels. euractiv.com.

Moreno-Peñaranda, R., Gasparatos, A., Stromberg, P., Suwa, A., Pandyaswargo, A.H., Puppim de Oliveira, J.A., 2015. Sustainable production and consumption of palm oil in Indonesia: What can stakeholder perceptions offer to the debate? Sustainable Production and Consumption, Sustainable Production and Consumption in Emerging Economies 4, 16–35. https://doi.org/10.1016/j.spc.2015.10.002

Morgans, C.L., Meijaard, E., Santika, T., Law, E., Budiharta, S., Ancrenaz, M., Wilson, K.A., 2018. Evaluating the effectiveness of palm oil certification in delivering multiple sustainability objectives. Environ. Res. Lett. 13, 064032. https://doi.org/10.1088/1748-9326/aac6f4

Moriarty, K., Elchinger, M., Hill, G., Katz, J., Barnett, J., 2014. Methane for Power Generation in Muaro Jambi: A Green Prosperity Model Project (No. NREL/TP-5400-62346). National Renewable Energy Lab. (NREL), Golden, CO (United States). https://doi.org/10.2172/1148620

Mukherjee, I., Sovacool, B.K., 2014. Palm oil-based biofuels and sustainability in southeast Asia: A review of Indonesia, Malaysia, and Thailand. Renewable and Sustainable Energy Reviews 37, 1–12. https://doi.org/10.1016/j.rser.2014.05.001

Neill, C., Jankowski, K., Brando, P.M., Coe, M.T., Deegan, L.A., Macedo, M.N., Riskin, S.H., Porder, S., Elsenbeer, H., Krusche, A.V., 2017. Surprisingly Modest Water Quality Impacts From Expansion and Intensification of Large-Sscale Commercial Agriculture in the Brazilian Amazon-Cerrado Region. Tropical Conservation Science 10, 1940082917720669. https://doi.org/10.1177/1940082917720669

Nepstad, D., McGrath, D., Stickler, C., Alencar, A., Azevedo, A., Swette, B., Bezerra, T., DiGiano, M., Shimada, J., Motta, R.S. da, Armijo, E., Castello, L., Brando, P., Hansen, M.C., McGrath-Horn, M., Carvalho, O., Hess, L., 2014. Slowing Amazon deforestation through public policy and interventions in beef and soy supply chains. Science 344, 1118–1123. https://doi.org/10.1126/science.1248525

OECD, 2015. Review of Agricultural Investment Policies of Ukraine.

Panagos, P., Borrelli, P., Poesen, J., Ballabio, C., Lugato, E., Meusburger, K., Montanarella, L., Alewell, C., 2015. The new assessment of soil loss by water erosion in Europe. Environmental Science & Policy 54, 438–447. https://doi.org/10.1016/j.envsci.2015.08.012

Panagos, P., Imeson, A., Meusburger, K., Borrelli, P., Poesen, J., Alewell, C., 2016. Soil Conservation in Europe: Wish or Reality? Land Degradation & Development 27, 1547–1551. https://doi.org/10.1002/ldr.2538

Paramitadevi, Y.V., Rahmatullah, 2017. Technical problems of wastewater treatment plant in crude palm oil industry A case study in PT Socfin Indonesia-Kebun Sungai Liput, Nang groe Aceh Darussalam Province. IOP Conf. Ser.: Earth Environ. Sci. 65, 012048. https://doi.org/10.1088/1755-1315/65/1/012048

Pauli, N., Donough, C., Oberthür, T., Cock, J., Verdooren, R., Rahmadsyah, Abdurrohim, G., Indrasuara, K., Lubis, A., Dolong, T., Pasuquin, J.M., 2014. Changes in soil quality indicators under oil palm plantations following application of 'best management practices' in a four-year field trial. Agriculture, Ecosystems & Environment 195, 98–111. https://doi.org/10.1016/j.agee.2014.05.005

Pennock, D., McKenzie, N., Montanarella, L., 2015. Status of the World's Soil Resources. Technical Summary FAO, Rome, Italy.

Reddington, C.L., Butt, E.W., Ridley, D.A., Artaxo, P., Morgan, W.T., Coe, H., Spracklen, D.V., 2015. Air quality and human health improvements from reductions in deforestation-related fire in Brazil. Nature Geoscience 8, 768–771. https://doi.org/10.1038/ngeo2535

Sanz-Cobena, A., Lassaletta, L., Estellés, F., Prado, A.D., Guardia, G., Abalos, D., Aguilera, E., Pardo, G., Vallejo, A., Sutton, M.A., Garnier, J., Billen, G., 2014. Yield-scaled mitigation of ammonia emission from N fertilization: the Spanish case. Environ. Res. Lett. 9, 125005. https://doi.org/10.1088/1748-9326/9/12/125005

Sauerbrei, R., Ekschmitt, K., Wolters, V., Gottschalk, T.K., 2014. Increased energy maize production reduces farmland bird diversity. GCB Bioenergy 6, 265–274. https://doi.org/10.1111/gcbb.12146

Scarlat, N., Dallemand, J.-F., 2011. Recent developments of biofuels/bioenergy sustainability certification: A global overview. Energy Policy 39, 1630–1646. https://doi.org/10.1016/j.enpol.2010.12.039

Schierhorn, F., Müller, D., Beringer, T., Prishchepov, A.V., Kuemmerle, T., Balmann, A., 2013. Post-Soviet cropland abandonment and carbon sequestration in European Russia, Ukraine, and Belarus. Global Biogeochemical Cycles 27, 1175–1185. https://doi.org/10.1002/2013GB004654

Scriven, S.A., Gillespie, G.R., Laimun, S., Goossens, B., 2018. Edge effects of oil palm plantations on tropical anuran communities in Borneo. Biological Conservation 220, 37–49. https://doi.org/10.1016/j.biocon.2018.02.006

Spera, S.A., Galford, G.L., Coe, M.T., Macedo, M.N., Mustard, J.F., 2016. Land-use change affects water recycling in Brazil's last agricultural frontier. Glob Chang Biol 22, 3405–3413. https://doi.org/10.1111/gcb.13298

Stefanoski, D.C., Figueiredo, C.C. de, Santos, G.G., Marchão, R.L., 2016. Selecting soil quality indicators for different soil management systems in the Brazilian Cerrado. Pesquisa Agropecuária Brasileira 51, 1643–1651. https://doi.org/10.1590/s0100-204x2016000900064

Strassburg, B.B.N., Brooks, T., Feltran-Barbieri, R., Iribarrem, A., Crouzeilles, R., Loyola, R., Latawiec, A.E., Filho, F.J.B.O., Scaramuzza, C.A. de M., Scarano, F.R., Soares-Filho, B., Balmford, A., 2017. Moment of truth for the Cerrado hotspot [WWW Document]. Nature Ecology & Evolution. https://doi.org/10.1038/s41559-017-0099

Stupak, N., 2016. Impact of Agricultural Transition on Soil Protection in Ukraine: The Role of Institutional Change. Land Use Policy 55, 86–97. https://doi.org/10.1016/j.landusepol.2016.03.022

Sutton, M.A., Howard, C.M., Brownlie, W.J., Skiba, U., Hicks, W.K., Winiwarter, W., van Grinsven, H., Bleeker, A., Westhoek, H., Oenema, O., 2017. The European Nitrogen Assessment 6 years after: What was the outcome and what are the future research challenges?

Tabassum, S., YeJian, Z., ZhenJia, Z., 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.

Tao, H.-H., Snaddon, J.L., Slade, E.M., Henneron, L., Caliman, J.-P., Willis, K.J., 2018. Application of oil palm empty fruit bunch effects on soil biota and functions: A case study in Sumatra, Indonesia. Agriculture, Ecosystems & Environment 256, 105–113. https://doi.org/10.1016/j.agee.2017.12.012

Tavares Wahren, F., Helm, B., Schumacher, F., Pluntke, T., Feger, K.-H., Schwärzel, K., 2012. A modeling framework to assess water and nitrate balances in the Western Bug river basin, Ukraine. Adv. Geosci. 32, 85–92. https://doi.org/10.5194/adgeo-32-85-2012

Trabaquini, K., Galvão, L.S., Formaggio, A.R., Aragão, L.E.O. e C. de, 2017. Soil, land use time, and sustainable intensification of agriculture in the Brazilian Cerrado region. Environ Monit Assess 189, 70. https://doi.org/10.1007/s10661-017-5787-8

TRASE, 2018. Sustainability in forest-risk supply chains: Spotlight on Brazilian soy - Trase Yearbook 2018. SEI & Global Canopy.

USDA FAS, 2018a. EU-28 Biofuels Annual 2017 (NL4025). United States Department of Agriculture Foreign Agricultural Service.

USDA FAS, 2018b. Brazil: Oilseeds and Products Annual.

USDA FAS, 2018c. Ukraine: Grain and Feed Annual 2018 (No. UP1809).

Varkkey, H., 2012. Patronage politics as a driver of economic regionalisation: The Indonesian oil palm sector and transboundary haze. Asia Pacific Viewpoint 53, 314–329. https://doi.org/10.1111/j.1467-8373.2012.01493.x

Vinken, G.C.M., Boersma, K.F., Maasakkers, J.D., Adon, M., Martin, R.V., 2014. Worldwide biogenic soil NOx emissions inferred from OMI NO2 observations. Atmospheric Chemistry and Physics 14, 10363–10381. https://doi.org/10.5194/acp-14-10363-2014

Wong, M.-K., Tsukamoto, J., Yusuyin, Y., Tanaka, S., Iwasaki, K., Tan, N.-P., 2016. Comparison of soil macro-invertebrate communities in Malaysian oil palm plantations with secondary forest from the viewpoint of litter decomposition. Forest Ecology and Management 381, 63–73. https://doi.org/10.1016/j.foreco.2016.09.011

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