Union Bioenergy Sustainability Report

Study to support reporting under Article 35 of Regulation (EU) 2018/1999

Guidehouse
September – 2023

EUROPEAN COMMISSION

Directorate-General for Energy
Directorate ENER— C: Green Transition and Energy System Integration
Unit C.2: Decarbonisation and Sustainability of Energy Sources

Contact: DG ENER, Unit C2

E-mail: ENER-UNIT-C2@ec.europa.eu

European Commission
B-1049 Brussels

Union Bioenergy Sustainability Report

Study to support reporting under Article 35 of Regulation (EU) 2018/1999

Final report

Directorate-General for Energy

2024

Directorate-General for Energy

2024

Manuscript completed in December 2023

1st edition

PDF	ISBN 978-92-68-11513-8	doi: 10.2833/527508	MJ-02-24-019-EN-N

Luxembourg: Publications Office of the European Union, 2024

Table of Contents

Executive summary

The Governance Regulation sets out the legal requirements and specific content for Member States (MSs) to report to the EC on the five dimensions of the Energy Union, including when to report and templates for the reports, which are further detailed in Commission Implementing Regulation (EU) 2022/2299 of 15 November 2022. The NECPRs submitted in the 2023 round were the first NECPRs with the new and updated formats, containing the requests as stated in the Governance Regulation.

In this report, we present the main findings of the quantitative and qualitative analysis regarding the production and consumption of bioenergy in each MS and in the European Union (EU-27) as a whole, as well as the main policies and measures implemented. Within this scope, we address the sustainability of the bioenergy consumption in the EU-27.

For the quantitative analysis, based on data provided by the MSs in their NECPRs, as well as Eurostat databases (e.g. Energy Balances, SHARES), we elaborated a set of graphs and tables to show the bioenergy shares across different categories, covering:

- Per sector: electricity, heating and cooling, and transport sectors (RES-E, RES-H&C, RES-T)
- Per bioenergy type: solid biomass, biogas, bioliquids and biofuels
- Per feedstock: agricultural biomass with a focus on food and feed, forest biomass, waste and residues, especially Annex IX feedstocks
- For the year 2021 and insights of the trend of previous years

As shown in Figure 1, **a total 148 Mtoe of bioenergy was consumed in the EU-27 in 2021, representing 58.9% of the total renewable energy market**. More than half of the total bioenergy consumption consisted of solid biomass (70.3%, in the figure see ‘solid biofuels’), followed by liquid biofuels (12.9%), and biogas (10.1%). Liquid biofuels, mostly used in the transport sector, were made up of 77.1% biodiesels and 16.6% biogasoline. Regarding biofuel demand, Annex IX biofuel consumption increased from 2,317 ktoe in 2017 to 5,474 ktoe in 2021, making up 2.1% of EU-27 fuel consumption in transport in 2021. Annex IX B (a), used cooking oil (UCO), is the most frequently used feedstock within the Annex IX biofuels (2,580 ktoe in 2021).

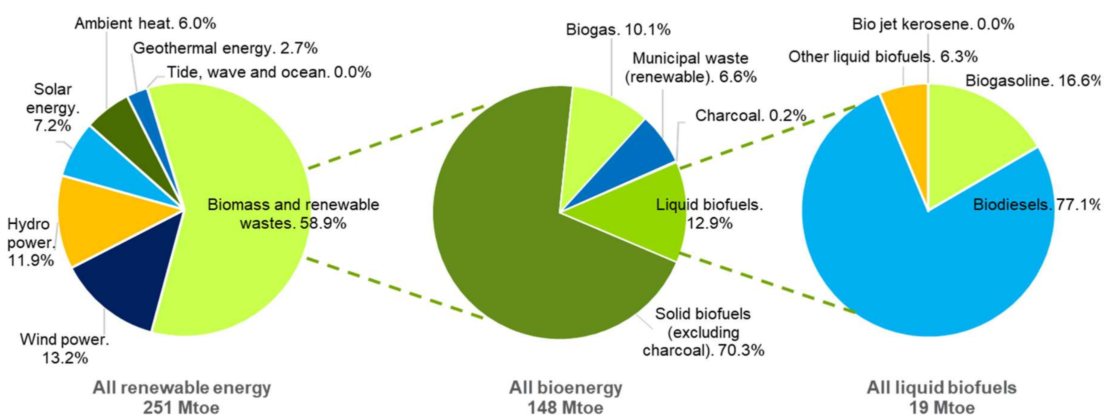

Figure 1: Gross EU consumption of renewable energy per type (2021, % and Mtoe). Source: Eurostat

The overall share of bioenergy as part of the total energy use differs per sector. Through SHARES the MSs reported 17 Mtoe of bioenergy used in the transport sector (without multipliers, this indicates a share of 6% of total fuels consumed in transport). With multipliers and other renewables, the total share of renewables in transport was 9,1% in 2021. Also in SHARES, MSs reported a total of 93 Mtoe of renewables used in their electricity sector in 2021 (37.6% of total electricity), to which solid biomass (excluding MSW) contributed with 7.6 Mtoe (8% of all renewables and 3% of all electricity generation). Lastly, MSs reported a total of 110.5 Mtoe of renewables in their heating and cooling sector in 2021 (22.9% of ‘all fuel consumed for heating and cooling), of which solid biomass (excluding MSW) was the largest renewable contributor with 84 Mtoe (76% of all renewables and 17% of all fuels consumed in heating and cooling).

In 2021, based on the Eurostat Energy Balances, the final consumption of biofuels in the EU transport sector was a total of 16.7 Mtoe in 2021.The EU electricity sector had a total gross electricity production of 249.9 Mtoe, of which a share of 5.8% was produced from biomass fuels and bioliquids. The EU heating sector had a total gross heat production of 56.0 Mtoe is of which a share of 30.9% was produced from biomass fuels and bioliquids. Please note that Energy Balances present data in final energy produced, while SHARES presents information in total fuels consumed.

Solid biomass is the biggest category within bioenergy consumption in 2021 and is mainly used in the heating sector and for electricity production. In the heating sector, solid biomass made up 76.0% of the heat production by biomass fuels and bioliquids, and 54.8% for electricity production in 2021. The residential sector uses 45.5% of the consumed solid biomass when accounting for the residential, industry, and energy sectors. Additionaly, the share of solid biomass can be further detailed for the industry, residential, and energy sectors. At the EU collective level in 2021, the industry sector consumed 21.1 Mtoe of solid biomass (8.8% of final energy consumed in the industry sector), the residential sector 45.2 Mtoe (17.3% of final energy consumed in the residential sector), and the energy sector 33.0 Mtoe (2.6% of transformation input in the energy sector).

The solid biomass production within the EU-27 has increased in 2021 compared to 2020 by more than 7% to 4,456 PJ. The increase is also evident in the indigenous production per individual MS, which increased in 23 out of 27 MS for the year 2021. Of all feedstocks, fuelwood, wood residues, and by-products make up the biggest category, representing 75.5% of all solid biomass production, as shown in Figure .

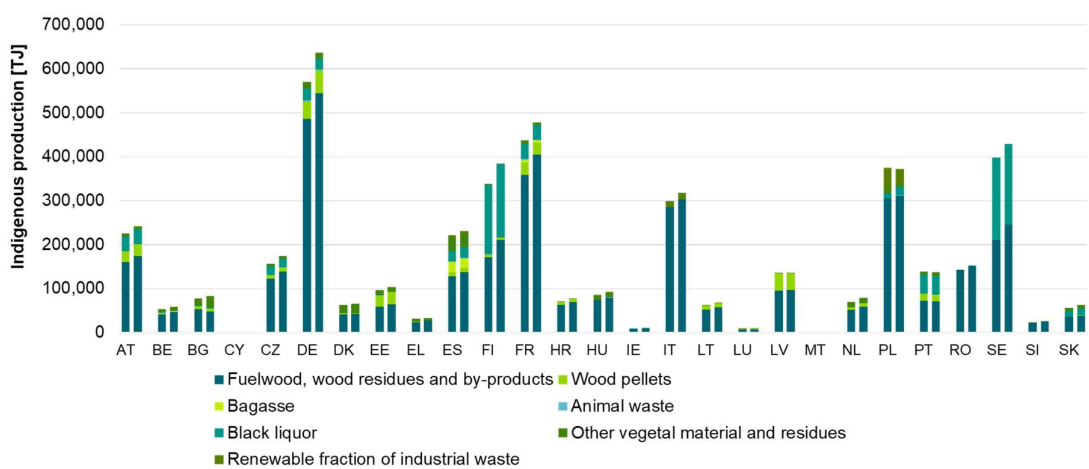

Figure 2: Indigenous production of solid biomass per MS in 2020 (left bar) and 2021 (right bar). Source: Eurostat table NRG_CB_RW

Biogases are mainly used for electricity production, representing 31.1% of biomass fuel and bioliquid demand of the electricity sector in 2021. The combined EU-27 indigenous biogas production was 12,789 ktoe in 2021, a 1.4% increase with respect to 2020 (12,609 ktoe).

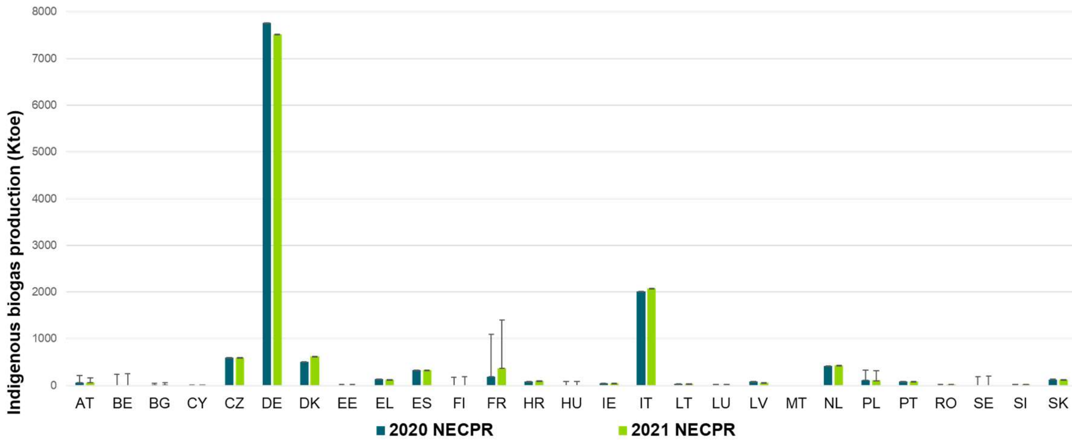

Figure 3: Indigenous biogas production in 2020 (left bar) and 2021 (right bar) per MS. The error bars visualize the difference with the values as reported in the Eurostat energy balances. Source: NECPRs and [NRG_BAL_C]

MSs are required to report on the measures they have implemented to **promote the use** of energy from biomass, including the sustainable biomass availability, as well as measures for the **sustainability of biomass** produced and used (Article 20(b)(8) of the Governance Regulation). Regarding measures for the **promotion of use** of energy from biomass, the most common reported measures either related to blending obligations for biofuels, financial incentives (such as grants, CAPEX subsidies, and support schemes), or strategies on feedstock availability or innovation and research. Regarding measures for **sustainability of biomass**, sustainability criteria are explicitly reported by 10 MSs in at least one of their reported measures. Some of the reported measures have already been implemented before 2020. Many reported measures are related to policies that are already ongoing, have been extended, or were implemented when REDI or REDII sustainability criteria were mentioned only as a prerequisite. There are limited measures reported that make explicit mention of updated regulations or implementation of the updated sustainability criteria in REDII.

Several MSs explicitly reported on measures aimed at stimulating the production and deployment of **advanced biofuels**. The measures reported either mention blending obligations or specific targets for advanced biofuel consumption or relate to incentives for production or enabling feedstock availability. **Biogas** is promoted across various industries including electricity, transport, energy and heating, industry and agriculture, and waste (listed in order from high to low frequency). 24 MSs reported a measure related to biogas. 11 MSs[1] reported on **forest biomass**, mostly related to electricity, energy, and/or heat generation. No MSs reported anything specific about challenges related to forest biomass availability in the measures they submitted.

21 MSs[2] submitted information regarding observed cases of **fraud**. Of these, only four MSs observed actual (or potential) cases of fraud, including Estonia, Hungary, Romania, and

1 These 11 MSs include Belgium, Denmark, Estonia, Finland, France, Ireland, Luxembourg, Portugal, Romania, Slovenia, and Spain.
2 The 21 MSs include Austria, Bulgaria, Croatia, Cyprus, Estonia, Finland, France, Germany, Hungary, Ireland, Italy, Latvia, Lithuania, Malta, the Netherlands, Poland, Portugal, Romania, Slovenia, Spain, and Sweden.

Sweden. Moreover, there were two cases of non-compliance in France, non-conformities found during audits reported in Italy, and some inaccuracies in procedures reported in the Netherlands.

MSs were also asked to reflect on potential environmental impacts and import dependency in their NECPRs. Within the NECPRs, **solid biomass** is reported in the following three categories: forest biomass, organic waste biomass, and agricultural solid biomass. According to the NECPRs, 19% of the forest biomass used for energy purposes was imported into the EU in 2021. When looking at the different feedstocks, 8% of the woodchips are imported, 34% of the wood pellets, and 6% of roundwood. The wood pellets are mainly imported from Russia (35%) and the USA (33%), but wood pellets make up only 9% of the total forest biomass used for energy. Environmental impacts related to wood chips and wood pellets are usually low, since most of these are made from forest residues and sawmill by-products. For roundwood, environmental impacts related to harvesting should be minimized through the application of the RED II sustainability criteria for forest biomass.

Sustainability risks are perceived low for the categories of renewable municipal waste, as well as agricultural residues (assuming that for the latter the additional RED II sustainability criteria related to soil quality and soil carbon were observed). For the renewable municipal solid waste, four MSs reported imports, most of which imported considerably less than a third of their total consumption.

No data is reported in the NECPRs or Eurostat concerning **biogas** feedstock and its trade, therefore, it is not possible to distinguish import dependencies for the category of biogas. This also hampers the indication of potential environmental risks. In general, it is assumed that most biogas is produced from manure, waste, or cover crops, which would have negligible environmental impacts and potentially even benefits. However, in the case that biogas is produced from crop-based feedstocks, similar potential environmental risks as for crop-based biofuels could occur.

Regarding biofuels, biodiesel is the most widely used biofuel in the EU. It is mainly produced from domestically cultivated rapeseed, which has relatively low environmental impacts. Other oil seeds grown in the EU have a very limited use for biodiesel currently. However, the second largest feedstock used to produce biodiesel is palm oil, for which all feedstock is imported. Palm oil has a very high yield compared to other oil seeds, so it has a high area efficiency. However, it is associated with high levels of land use change and is classed as a high ILUC-risk feedstock, according to the rules included in the Commission Delegated Regulation (EU) 2019/807, thus will have to be phased out by 2030. Palm oil currently contributes to 14% of EU biodiesel production; as such, this gap will need to be filled by alternative feedstocks. As palm yield is typically two to three times higher than that of other oil seeds, this gap could be significant. Another frequently used crop-based biofuel is bioethanol. Currently, bioethanol is produced mainly from EU-grown sugar beet, corn, and wheat (16.1%), with 1.4% from other EU-grown crops. Sugar cane is 100% imported, but only contributes 0.2% of bioethanol.

The feedstocks with a risk of high import dependency on non-EU suppliers include palm oil, soy, used cooking oil, sugar cane, and wood pellets. Palm oil is 100% imported, primarily from Indonesia (65%) and Malaysia (29%). Meanwhile, 87% of soy is imported, mostly from Brazil (46%), the USA (24%), and Argentina (21%). 56% of UCO is imported, mainly from China (37%), Malaysia (13%), and Indonesia (11%). 100% of sugar cane is imported from Brazil. These feedstocks, however, are not the major feedstocks used in their respective bioenergy categories. Palm oil makes up 15% of the total liquid biofuels in the EU in 2021, while sugar cane makes up 1% of the total bioethanol.

Directorate-General for Energy

2024

Abbreviations

ABP(s)	Animal by-product(s)
BioCNG	Bio-compressed natural gas
BioLNG	Bio-liquefied natural gas
BioNGV	Bio-natural gas for vehicles
BSE	Bovine Spongiform Encephalopathy
CAP	Common Agriculture Policy
CAPEX	Capital expenditures
CAPRI	Common Agriculture Policy Regionalized Impact (Model)
CD	Casual-descriptive models
CHP	Combined Heat and Power
CPI	Current Policy Initiatives
DH	District Heating
DNI	Direct normal irradiance
DSO	Distributed System Operator
EBA	European Biogas Association
EC	European Commission
ECS	Coordinating Entity (of Portugal) for Compliance of Biofuel Sustainability Criteria
EFB(s)	Empty palm fruit bunche(s)
EFPRA	European Fat Processors and Renderers Association
ETBE	Ethyl Tert-butyl Ether
EV	Electric Vehicle
EU	European Union
FAME	Fatty Acid Methyl Ester
FAPRI	Food and Agricultural Policy Research Institute (Model)
FAPRI-CARD	Food and Agricultural Policy Research Institute – Centre for Agricultural and Rural Development (Model)
FASOM	Forest and Agricultural Sector Optimization Model
FIP	Feed-in premium
FIT	Feed-in tariff
GC	Green certificates
GHG	Greenhouse gas
GO(s)	Guarantee(s) of Origin
HDD	Heating Degree Days
HEFA	Hydroprocessed Esters and Fatty Acids
HVO	Hydrotreated vegetable oil
ICCT	International Council on Clean Transportation
ILUC	Indirect Land Use Change
ILUC Directive	DIRECTIVE (EU) 2015/1513
IRW	Industrial roundwood
ISCC	International Sustainability & Carbon Certification
IUCN	International Union for Conservation of Nature
LCA	Life cycle assessment
LCOE	Levelized cost of electricity
LNG	Liquefied natural gas
LULUCF	Land use, land use change, & forestry
MS(s)	Member State(s)
MSPO	Malaysia Sustainable Palm Oil
MSW	Municipal solid waste
NDC	Nationally Determined Contribution
NECP	National Energy and Climate Plan
NECPR	National Energy and Climate Progress Report
No.	Number
NREAP	National Renewable Energy Action Plan
NTR ID	National Trade Register Identifier
OPEX	Operating expenses
PoS	Proof of Sustainability
PPI	Planned Policy Initiatives
RED	Renewable Energy Directive
REDI	Renewable Energy Directive 2009/28/EC
REDII	Recast of the Renewable Energy Directive (DIRECTIVE (EU) 2018/2001)
RES	Renewable Energy Sources
RES-H&C	Renewable Energy Share in Heating and Cooling sector
RES-E	Renewable Energy Share in Electricity sector

RES-T	Renewable Energy Share in transport sector
RFNBO	Renewable liquid and gaseous transport fuels of non-biological origin
RSPO	Roundtable on Sustainable Palm Oil
POME	Palm oil mill effluent
PSA	Pressured water scrubbing
PWA	Pressure swing absorption
SAF	Sustainable Aviation Fuel
SEK	Swedish Krona
SOC	Soil organic carbon
SOM	Soil Organic Matter
TSO	Transmission System Operator
UCO	Used cooking oil
UDB	Union database
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar

1. Introduction

To facilitate the transition away from fossil fuels towards cleaner energy, and to deliver on the EU's Paris Agreement commitments to reduce greenhouse gas (GHG) emissions and the European Green Deal, the EU has established a comprehensive climate and energy package. The ‘Clean Energy for all Europeans’ package was adopted in 2019, providing a new set of rules that aim to update the European energy policy framework and consisting of eight wide-ranging laws including Directives on renewable energy, energy efficiency, and the energy performance of buildings This package also includes the Governance Regulation (EU) 2018/1999 which represents the first horizontal piece of legislation to address energy and climate policy in an integrated manner across the five dimensions of the Energy Union.

Thereby, the Governance Regulation establishes the governance mechanism with the goal to define a robust and transparent system of reporting and governance between the European Commission (EC) and the Member States (MSs) regarding energy and climate action. This governance mechanism is based on a reporting system of integrated national energy and climate plans (NECPs), EU and national long-term strategies, as well as corresponding integrated reporting and monitoring arrangements, including biennial integrated national energy and climate progress reports (NECPRs) from the MSs to the EC, starting in 2023.

The Governance Regulation further sets out the legal requirements and specific content for MSs to report to the EC on the five dimensions of the Energy Union, including when to report and templates for the reports, which are further detailed in Commission Implementing Regulation (EU) 2022/2299 of 15 November 2022.

The aim is to ensure the alignment of national and EU trajectories and their consistency with decarbonisation ambitions. Ultimately, the intention is to facilitate a transparent and coordinated planning, reporting, and monitoring process and to promote closer cooperation between MSs in these dimensions.

Union bioenergy report as part of the State of the Energy Union report

Article 35 of the Governance Regulation provides that by 31 October of every year, the EC must submit a State of the Energy Union report. The report takes stock of the progress made towards building the Energy Union and highlights the issues in which further attention is needed. As part of that report, Article 35 (2)(d) specifies that every two years, starting in 2023, the EC shall publish a report on Union bioenergy sustainability.

Previously, the EC’s reporting on the sustainability of bioenergy was based on Articles 23 and 17 (7) of the Renewable Energy Directive 2009/28/EC (‘REDI’). With the introduction of the Governance Regulation and the recast of the RED to the REDII (Directive (EU) 2018/2001), the reporting requirements are updated and moved into the Governance Regulation. Thus, Article 35 (2) of the Governance Regulation now adjusts the scope of the reporting obligation of the EC, with Annex X of that Regulation specifying the minimum information to be included.

A key difference in the EC’s bioenergy sustainability reporting under the Governance Regulation is that the scope of reporting is now extended across the board to include bioliquids and biomass fuels (i.e. all bioenergy used for heat and electricity), rather than the previous scope which was limited to biofuels used in transport. This reflects the increased scope of the sustainability criteria in the REDII to cover heat and electricity applications, as well as transport. Furthermore, the new reporting requirements include further detailed analysis of Annex IX feedstocks (d), more detail on what the reporting should focus on with respect to indirect land-use change (e), reporting on national measures taken to respect sustainability and GHG criteria (f), and a new requirement to consider the data from the European Union (Union) database, which is in the process of being piloted and populated with the first data at the time of writing.

Relevance of reporting requirements

This reporting provides key information that feeds into the ongoing dialogue between the EC and MSs to help ensure coherence between national and Union policies and objectives of the Energy Union. Moreover, it contributes to a holistic overview of current developments in the MSs. This overview, supplemented by in-depth research and studies, helps the European Parliament and the Council to more accurately track the progress achieved by the Energy Union on all dimensions of energy and climate policies.

Specifically, reporting is necessary to assess the overall impact of the policies and measures of the NECPs on the operation of the Union climate and energy policy measures. This supports the assessment of the need for additional Union policies and measures in view of the necessary increase in GHG emission reduction and removals in the Union to meet the commitments under the Paris Agreement. EU policy in this area is advancing particularly quickly, meaning that solid data on the status and progress is crucial. This is not only as the evidence mounts for increasing ambition required on climate action, which led also to the publication of the “Fit for 55” package in summer 2021, but also the urgency to increase EU energy security as brought about by the invasion of Ukraine by Russia, which led to the 2022 REPowerEU plan. Both “Fit for 55” and REPowerEU aim to drive faster deployment of renewable energy in all sectors across the EU.

In light of a required update of the NECPs by the MSs by June 2023, this study supporting reporting under Article 35 of the Governance Regulation will provide the EC with an updated status report on bioenergy deployment and sustainability and can provide input for the update of the NECPs to tackle specific (bioenergy) topics that arise during the assessment.

Aim of the study

The sustainability of bioenergy is a complex and ever-evolving area of policy. It is crucial for MSs and the EC to have a strong and consistent understanding of the different sources of bioenergy that are being used, as well as their environmental impacts and potential risks, to ensure that policies and measures can be steered to ensure sustainable bioenergy markets.

The objective of the study for the EC is, therefore, to support the EC’s work towards fulfilling its obligation set out in Article 35 of the Governance Regulation (EU) 2018/1999, to issue a Union bioenergy sustainability report by 31 October 2023. The study will gather and consolidate relevant data from MS NECPRs and other external sources as necessary to provide an analysis covering all the minimum items listed in Annex X of the Governance Regulation and listed in Table 1 in this chapter.

The outcome of the study will also be used for the assessment of progress of MSs and the EU towards meeting the objectives of the Energy Union and MSs’ NECPs, pursuant to Article 29 of the Governance Regulation, and to provide guidance to MSs to improve their future NECPRs.

.

2. Bioenergy supply and demand and market and technological developments

2.1. Introduction

This chapter establishes a common starting point with regard to bioenergy in the EU. Describing the current state of play of biofuels, bioliquids, and biomass fuels helps to distinguish developments in the availability, origin, and use of biomass resources for energy purposes. Various perspectives are employed to develop insights in the role of bioenergy in the EU as a whole, as well as per MS.

Firstly, the terminology and data sources that are used in this report are outlined to create a common understanding of concepts and sources. Secondly, the production of biofuels and biogases, as well as the supply of biomass fuels are described, together with their origins. Thirdly, the demand of biofuels, bioliquids, and biomass fuels is distinguished for the transport, electricity, and heating sectors. Fourthly, the impact of biofuels, bioliquids, and biomass fuels on commodity prices and land use are identified. Finally, technology developments in Annex IX biofuels are specified by summarizing developments in production technologies, as well as deployment.

2.1.1. Approach and data sources

Terminology

In this report, we apply the classifications and definitions that are specified by the Renewable Energy Directive (Directive 2009/28/EC), updated by the recast of the Directive to the REDII (Directive (EU) 2018/2001). This is in line with the reporting requirements as put forth in the Governance Regulation (EU) 2018/1999. We present the main terminology used in the following sections to ensure common understanding of definitions and concepts throughout the report. This is especially important, for example, in comparison with Eurostat Energy Balances, as there are differences in terminology and classifications applied. In this report we use the RED terminology in the text and descriptions, but in some graphs directly based on the Energy Balances, labelling was kept consistent with the original data source.

In the following section we present and clarify the main terminology.[3]

The overall scope of this report includes the following concepts:

- There is no specific definition for bioenergy in the RED, but refers to energy (in any form, such as heat, electricity, or energy carriers) produced from a type of biomass.
- Biomass, according to Article 2(24) of REDII, means the *biodegradable fraction of products, waste and residues from biological origin from agriculture, including vegetal and animal substances, from forestry and related industries, including fisheries and aquaculture, as well as the biodegradable fraction of waste, including industrial and municipal waste of biological origin*.
- Biomass fuels, according to Article 2(27) of REDII, refer to gaseous and solid fuels produced from biomass (for example, biogas or wood pellets)

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

- Solid biomass has no specific definition in the RED but 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

3 All terminology presented is based on REDI and REDII, supplemented by the ILUC Directive.

other vegetal materials excluding charcoal and the biodegradable 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 from Eurostat use the term "primary solid biofuels" to refer to solid biomass. However, since "biofuels" in the RED framework are associated with liquid fuels for transport, the term is avoided in this report when solid biomass fuels are used in sectors other than transport. Energy statistics from Eurostat use the term "renewable municipal waste" instead of "biodegradable fraction of municipal solid waste", this report will use the terminology from Eurostat.

- Biogas, according to Article 2(28) of REDII, is *gaseous fuel produced from biomass*, mostly via anaerobic digestion and possibly (in future) via gasification and methanisation. Biogas includes (pure) biomethane. Biogases are not further distinguished in the Energy Balances. Biogas is currently used either for the generation of heat and electricity or it is upgraded to natural gas quality and injected into the gas grid as biomethane. Biomethane can also be used in transport.
- Bioliquids, according to Article 2(32) of REDII, are *liquid fuels for energy purposes other than for transport, including electricity and heating and cooling produced from biomass.* The term is only used for liquid biomass used to generate electricity and heat (and possibly cooling). It is likely to include vegetable oil or pyrolysis oil. Yet, black liquor, a liquid residue from pulping process is recorded under 'Primary solid biofuels' in Energy Balances. From a chemical and physical point of view, these materials could be the same as biofuels. Hence, the application is essential in the definition of bioliquids.
- Biofuels, according to Article 2(33) of REDII, are *liquid fuels for transport produced from biomass*, thereby replacing fossil gasoline, diesel, or other fossil energy carriers.

When information is presented based on the solid biomass questionnaire (as per MSs NECPR reporting obligation[4]), the categorisation from the Governance Regulation 2018/1999 Annex IX Part 1 point (m) is applied (categorising primary supply of solid biomass in forest biomass, agricultural biomass and organic waste biomass). See section 2.2.1 for a further split of each of these categories in the underlying sub-categories.

Terminology for renewable energy in transport

For the share of renewable energy in transport, several types of energy can be applied:

- Biofuels, as mentioned above (liquid fuels used in the transport sector), can be dividied into the following categories:
    - 'Advanced biofuels', according to Article 2(34) of REDII, means *biofuels that are produced from the feedstock listed in Part A of Annex IX*
    - Biofuels produced from the feedstock listed in Part B of Annex IX, which currently only includes used cooking oil and animal fats classified as categories 1 and 2 in accordance with Regulation (EC) No 1069/2009.
    - 'Biofuels from food and feed crops', according to Article 2(40) of REDII, refer to *biofuels produced from starch-rich crops, sugar crops, or oil crops produced on agricultural land as a main crop excluding residues, waste or ligno-cellulosic material, and intermediate crops, such as catch crops and cover crops, provided that the use of such intermediate crops does not trigger demand for additional land.* These can include biodiesel based on palm or soy, or bioethanol based on maize or sugar cane.
    - Biofuels produced from high indirect land use change (ILUC)-risk feedstocks are those for which a significant expansion of the feedstock production area into land with high carbon stock is observed, according to the rules included in the Directive and following the methodology of the Delegated Regulation (EU)

4 Supply of biomass - annual data https://ec.europa.eu/eurostat/databrowser/view/NRG_CB_BM

2019/807. Currently, following the above-mentioned methodology, only palm oil is considered a high ILUC-risk feedstock.
    - Low ILUC-risk biofuels, bioliquids and biomass fuels, according to Article 2(37) of REDII, are *biofuels, bioliquids and biomass fuels, the feedstock of which was produced within schemes which avoid displacement effects of food and feed-crop based biofuels, bioliquids and biomass fuels through improved agricultural practices as well as through the cultivation of crops on areas which were previously not used for cultivation of crops, and which were produced in accordance with the sustainability criteria for biofuels, bioliquids and biomass fuels laid down in Article 29.*

- Renewable liquid and gaseous transport fuels of non-biological origin (RFNBO), according to Article 2(36) of REDII, means liquid *or gaseous fuels which are used in the transport sector other than biofuels or biogas, the energy content of which is derived from renewable sources other than biomass*. A common example is renewable hydrogen. The two main production pathways are electrolysis based on renewable electricity and gasification.
- Electricity in road or rail, for which only the renewable share is counted as renewable energy in transport.
- Biogas (see description above) applied in road or maritime transport.
- Recycled carbon fuels, according to Article 2(35) of REDII, refer to *liquid and gaseous fuels that are produced from liquid or solid waste streams of non- renewable origin which are not suitable for material recovery in accordance with Article 4 of Directive 2008/98/EC, or from waste processing gas and exhaust gas of non-renewable origin which are produced as an unavoidable and unintentional consequence of the production process in industrial installations*.

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

Data sources

Some of the data that is used in the analyses in this report come from sources or databases that are prone to changes and/or are regularly updated. To clarify which version of such datasets is included in the analyses, Table 1 provides an overview of the latest extraction date of each dataset.

Table 1: Overview of data sources and related extraction dates.

Data source	Latest extraction date	Used in section
Eurostat Infrastructure [NRG_INF]	12 May 2023	2.2.1
Eurostat Energy Balances [NRG_BAL_C]	26 April 2023	2.3.1, 2.3.2, 2.3.3, 2.4.2
Eurostat SHARES database	7 June 2023	2.3.1
Eurostat EU trade since 1988 by HS2-4-6 and CN8	9 August 2023	2.2.1, 2.4.2
Eurostat table [NRG_CHDD_A]	1 June 2023	2.3.2
Statista biofuel production volumes	2 June 2023	2.4.1
Word Bank monthly commodity prices	2 June 2023	2.4.1
NECPR Annexes	4 September 2023	2.2.1, 2.2.2, 2.2.4, 2.4.1, 2.4.2, 2.5.2, 2.5.4

FAO Crops and livestock products	31 July 2023	2.4.2
FAO Land use	13 July 2023	2.4.2
Draft updated NECP	13 September	2.3
Supply of biomass - annual data [NRG_CB_BM]	29 June 2023 (last data update)	2.2.1

2.2. Shares of current and projected primary supply of biomass by feedstock and origin

2.2.1. Current primary supply of biomass by feedstock and origin

This section describes the primary supply of biomass by MS and by feedstock, as reported by MSs in their NECPRs and via the solid biomass questionnaire. Note that this section focuses on biogas and biofuel production and biomass supply per MS, which is not necessarily the same as biomass consumption for energy purposes per MSs, as fuels can be traded across borders. In Figure 4, an overview of biomass consumed across all forms of renewable energy in the EU in 2021 is presented.

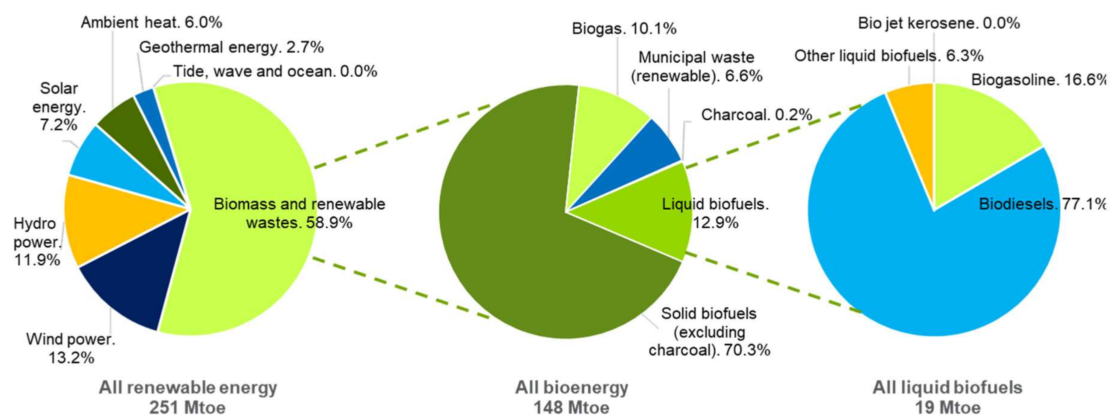

Figure 4: Gross EU consumption of renewable energy per type (2021, % and Mtoe). Source: Eurostat

Solid biomass

All MSs except Hungary reported their indigenous production through the solid biomass questionnaire as per their NECPR reporting obligation. These are reported on a volume basis (1,000 m^3) in Eurostat.[5] The categorisation is based on the Governance Regulation 2018/1999 Annex IX Part 1 point (m). The three main categories of primary supply of solid biomass used for energy production introduced in the Governance Regulation are forest biomass, agricultural biomass, and organic waste biomass. Within forest biomass, MSs can distinguish between primary biomass from forest (branches and tree tops, stumps, and round wood), forest-based industry co-products (bark, chips, sawdust and other wood

5 Supply of biomass - annual data https://ec.europa.eu/eurostat/databrowser/view/NRG_CB_BM

particles, and black liquor and crude tall oil), post-consumer wood, and processed wood-based fuel produced from other feedstocks not accounted for in the previously named categories. Agricultural biomass is the sum of energy crops and agricultural residues, specifically for electricity or heat. Organic waste biomass is split in organic fraction of industrial waste, organic fraction of municipal waste and waste sludges. This categorization is used in all figures based on the data provided through the solid biomass questionnaire (NRG_CB_BM), namely: Figure 5, Figure 6, Figure 7, Figure 10, Figure 11, Figure 13, and Figure 15.

In the EU, the main reported category for indigenous production of solid biomass by volume is forest biomass (66%), followed by biomass from organic waste (26%) and agricultural biomass (8%) (Figure 5). When looking at the reported values at the MS level, Germany dominates the right side of the graph with their production of organic waste biomass (137,675 thousand m^3). Sweden (65,102 thousand m^3) and Germany (66,658 thousand m^3) have the largest amount of forest biomass production among the MSs. Spain has the highest volumes of agricultural biomass (20,844 thousand m^3), which aligns with various measures reported that prioritize agricultural feedstocks for energy production (see section 3.2).

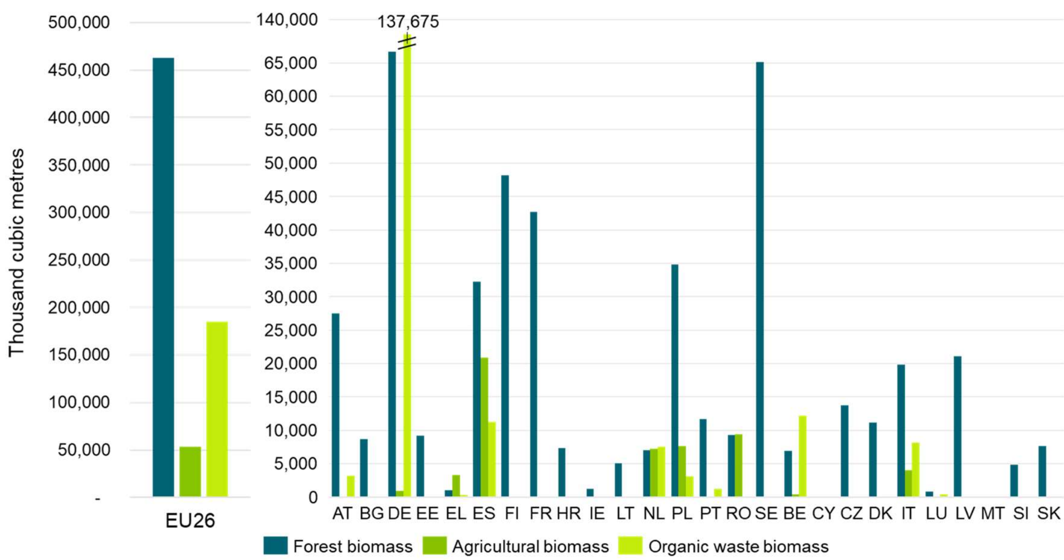

Figure 5: Primary supply of solid biomass in 1000 m3 for energy production, indigenous production in 2021. Source: Eurostat Supply of biomass - annual data (NRG_CB_BM)[6]

The volumes of solid biomass produced per MS (see Figure 6 below) show Germany leading with their reported total production values, mainly due to their large share of renewable municipal waste. The largest reported category by volume across the MSs was primary biomass from forest (262,858 thousand m^3 – 36% of the total). The leading country in reporting was Germany, claiming 12% of the total reported production of primary biomass from forest, followed by Spain and Poland that both reported 11%, and Sweden and France that both reported 10%. The second largest category by volume was renewable municipal

6 Categorisation as per Governance Regulation 2018/1999 Annex IX Part 1 point (m). (1) Forest biomass includes (a) primary biomass from forest, (b) forest-based industry co-products, (c) post-consumer wood, and (d) processed wood-based fuel. (a) Primary biomass from forest includes (i) branches and tree tops, (ii) stumps and (iii) roundwood split into industrial roundwood and fuelwood. (b) Forest-based industry co-products includes (i) bark, (ii) chips, sawdust and other wood particles, and (iii) black liquor and crude tall oil. (d) Processed wood-based fuel includes feedstocks that do not fall under the other categories, such as (i) wood charcoal and (ii) wood pellets and wood briquettes. (2) Agricultural biomass includes (a) energy crops including short rotation coppice and (b) agricultural crop residues. (3) Organic waste biomass includes (a) renewable fraction of industrial waste, (b) organic fraction of municipal waste and (c) waste sludges

waste (171,023 thousand m^3 – 24% of the total). Germany reported the vast majority within this category (74% of the total production of renewable municipal waste), followed by Sweden (8%), Belgium (6%), Spain and the Netherlands (both reported 4% of the total), Italy (2%), and Austria and Portugal (both reported 1% of the total). The third largest category of solid biomass production was forest-based industry co-products (144,821 thousand m^3 – 20% of the total). The highest reporting country was Sweden, with 22% of the total reported forest-based industry co-products, followed by Finland (20%), Austria (11%), Germany (10%), France (6%), Poland (5%), Estonia (4%), and Latvia (4%).

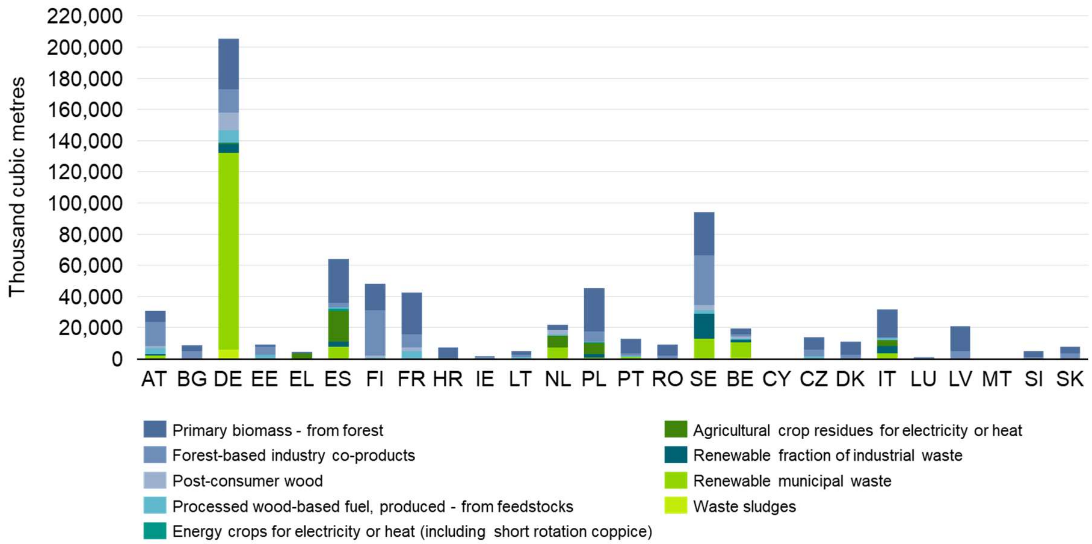

Figure 6*: Detailed overview of the reported indigenous production of solid biomass in the EU MSs in 2021, excluding black liquor. Source: Eurostat Supply of biomass – annual data (NRG_CB_BM)*

Figure 7 portrays the produced volumes of feedstocks reported in the EU in a higher level of detail. According to the Governance Regulation Annex IX Part 1 point (m), all data should be reported in thousand cubic metres, except black liquor and crude tall oil, which is to be reported in tonnes. However, Eurostat does not make this distinction when portraying or downloading the data. This causes black liquor to stand out among the other feedstocks in the detailed overview, as seen in Figure 7 below. Furthermore, black liquor should be a subset of 'forest-based industry co-products' according to the Governance Regulation Annex IX Part 1 point (m). When aggregating the data manually, the total for the forest-based industry co-products is 144,820 thousand m^3, while the total for black liquor is 46,000,658 m^3. The countries with the largest share of black liquor production were Sweden with 34% of the total amount of black liquor reported, Finland (33%), France (8%), and Germany (7%). The second largest category of solid biomass production is fuelwood with a total of 176,304 thousand m^3. The main countries reporting production within this feedstock were Poland (16% of the total fuelwood reported), France (15%) and Germany (14%), followed by Finland (10%), Italy (7%), Denmark (5%). Czechia, Croatia, Romania, and Austria eachhad a 4% share.. The third largest category, which is renewable municipal waste, closely followed fuelwood with a total of 171,023 thousand m^3 produced.

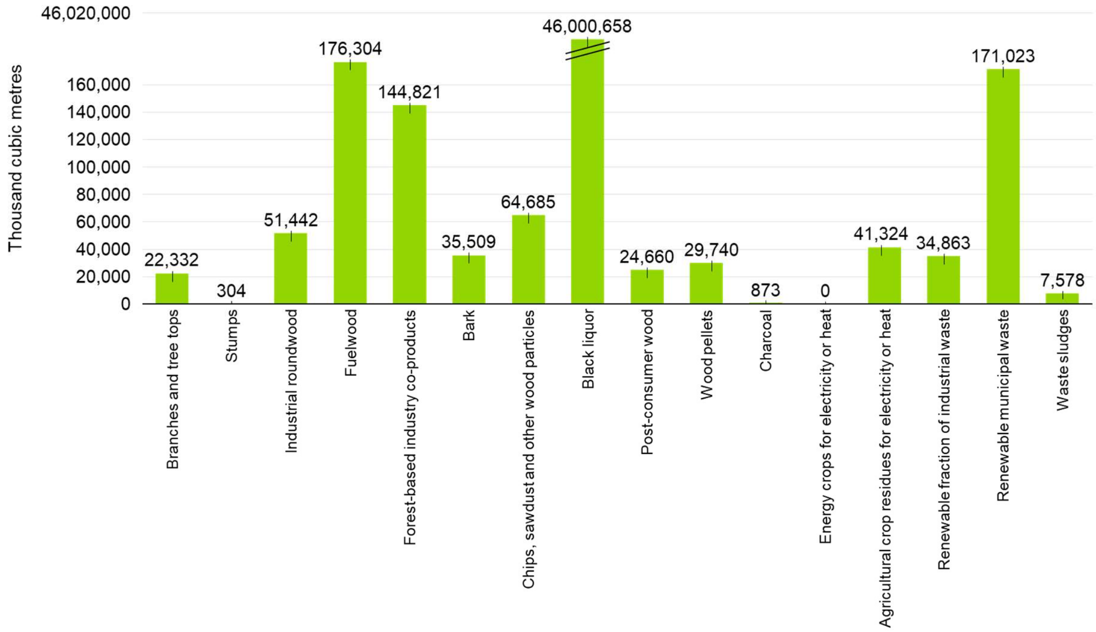

Figure 7: Detailed overview per feedstock (using the feedstock categories from the Governance Regulation Annex IX Part 1 point (m)) of all MSs[7] on the amount of solid biomass used for energy, indigenous production in 2021. Source: Eurostat Supply of biomass – annual data (NRG_CB_BM)

Both the Energy Balances (see section below) and the data included in the NECPR through the solid biomass questionnaire (as presented above) report broadly on the same topic, namely solid biomass. However, they fundamentally differ from one another in set up which allows for different insights into the same topic. Both datasets are presented in this report. The Energy Balances include 2020 and 2021, whereas the NECPR solid biomass questionnaire covers 2021. The units are different as well; Energy Balances are reported in TJ, while the NECPR data is reported in thousand m³. Furthermore, the NECPR solid biomass questionnaire allows for a more detailed overview of the different feedstocks, whereas the Energy Balances only include some of the feedstock categories (such as black liquor and wood pellets).

In the following section, we present insights based on the solid biomass data as presented in the Energy Balances. In Figure 8 below the indigenous production of different types of solid biomass is visualized, based on Eurostat Energy Balances data [table: NRG_CB_RW].[8]

In 2020, Germany was the EU-27's largest producer of solid biomass representing 15.5% (699,407 TJ) of EU total, followed by France (10.8%, 488,585 TJ), Sweden (9.6%, 433,092 TJ), Poland (8.4%, 381,325 TJ), Finland (7.8%, 351,487 TJ), Italy (7.4%, 333,560 TJ), Austria (5.2%, 233,776 TJ), Spain (5.1%, 231,022 TJ), Czechia (3.5%, 160,162 TJ), and Romania (3.2%, 142,499 TJ). Estonia produced 2.2% of solid biomass (98,156 TJ) and Greece 0.7% (31,430 TJ).

Accounting for 15.9% (767,891 TJ) of total solid biomass produced in 2021, Germany was again the EU's biggest producer, followed by France (11.0%, 530,659 TJ), Sweden (9.5%, 460,620 TJ), Finland (8.3%, 352,535 TJ), Poland (7.8%, 377,690 TJ), Italy (7.3%, 352,535 TJ), Austria (5.2%, 250,710 TJ), Spain (5.0%, 242,835 TJ), Czechia (3.7%, 177,519 TJ),

7 Except Hungary
8 Supply, transformation and consumption of renewables and wastes (online data code NRG_CB_RW)

and Romania (3.1%, 151,872 TJ). Estonia produced 2.2% of solid biomass (104,208 TJ) and Greece 0.7% (33,317 TJ).

It is worth noting that Finland and France both reported policy measures in their NECPRs promoting solid biomass production (see section 3.2). An (indirect) measure reported by France entitled, ‘The National Forest and Wood Program and Regional Forest and Wood Programs’, aims to mobilize an additional 12 m^3 of wood per year by 2026 compared with 2015 with the goal of strengthening the upstream and downstream forestry sector, the latter of which reportedly includes the development of biomass-based renewable energies. The measure was implemented in 2016. Finland reported a measure with the goal of increasing the number of wood fuel terminals, which stimulates solid biomass production. A start or end date of the measure is not reported in Finland’s NECPR.

Malta did not produce any solid biomass. Other smaller producers were Cyprus with 0.02% (1,056 TJ) in 2020 and 0.02% (1,162 TJ) in 2021, and Luxembourg with 0.2% (8,918 TJ) in 2020 and 0.2% (9,521 TJ) in 2021. Solid biomass production (in energy content) increased between 2020 and 2021 in all MSs except for Latvia, Poland, and Portugal, where slight decreases were observed. Fuelwood, wood residues, and by-products are the main type of solid biomass produced by energy content in each MS. In Romania, only fuelwood, wood residues, and by-products are generated, and in Italy, fuelwood, wood residues, and by-products, as well as renewable fraction of industrial waste are produced. Sweden and Finland stand out as the EU’s main producers of black liquor, whereas Poland’s relatively large production of the renewable fraction of industrial waste is notable. Lastly, Spain’s production of other vegetal materials and residues is considerable.

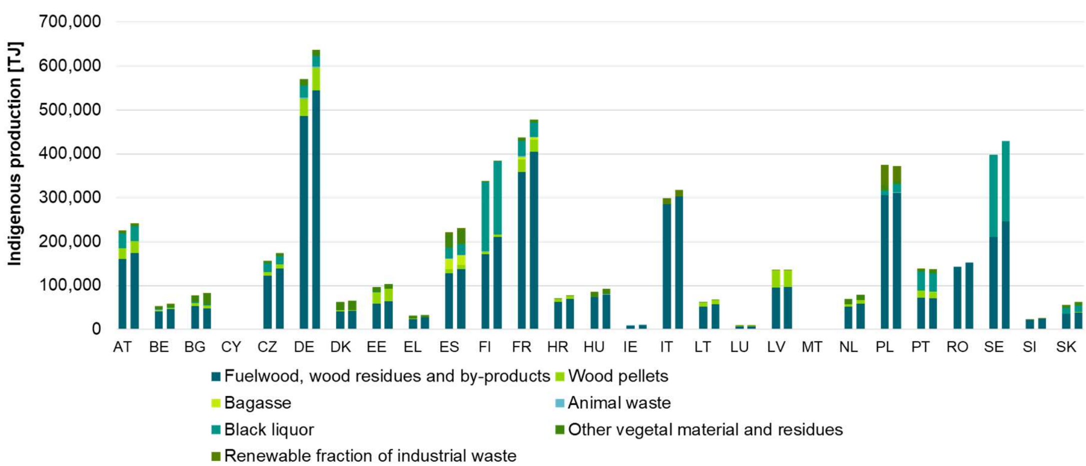

Figure 8: Indigenous production of solid biomass (in TJ) per MS in 2020 (left bar) and 2021 (right bar). Source: Eurostat table NRG_CB_RW

The EU’s total solid biomass production by volume over the years is presented in **Error! Reference source not found.** (based on the Eurostat Energy Balances). The production fluctuated slightly over the years, but over the full period grew from 3,336,811 TJ in 2008 to 4,454,768 TJ in 2021, an increase of 33.5% overall. Fuelwood, wood residues, and by-products are the largest source of solid biomass by energy in absolute terms, followed by black liquor. Of the different types of solid biomass produced, wood pellets displayed the largest growth over the period since the introduction of REDI in 2008 (413%), followed by animal waste (351.9%), the renewable fraction of industrial waste (58.6%), fuelwood, wood residues, and by-products (29.5%), and black liquor (25%). With a decrease of 8.8%, other vegetal material and residues were the only solid biomass type to reduce in production compared to 2008.

Due to differences in categorizations of types of solid biomass, no comparison is presented between the data from the Energy Balances to NECPR data from the biomass questionnaire (as presented at the start of the section).

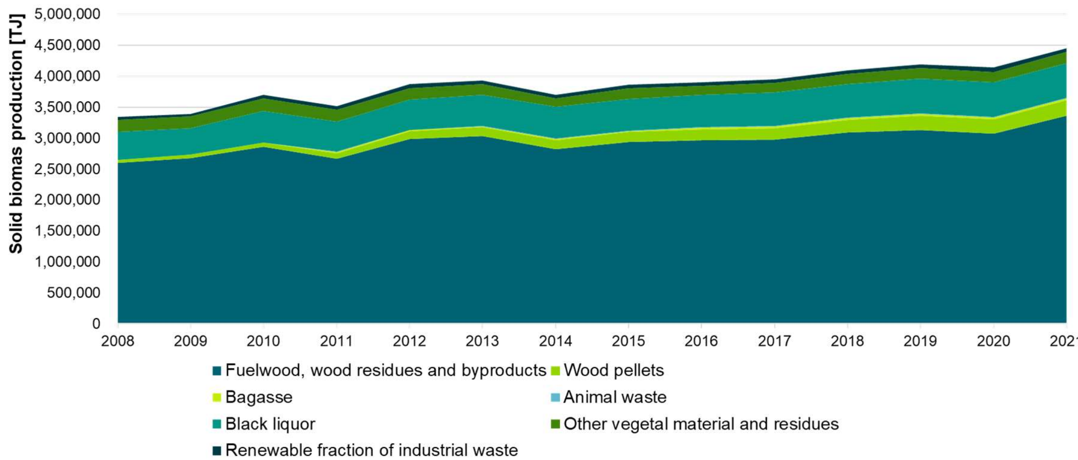

Figure 9: Total EU-27 solid biomass production (in TJ). Source: Eurostat table NRG_CB_RW

Import of solid biomass

Regarding solid biomass, 24 MSs reported imported volumes of solid biomass in the Eurostat biomass questionnaire.[9] Spain, Romania, and Luxembourg did not report imports of solid biomass. Imports of agricultural biomass and stumps were left empty in all MS reports.

Imports of solid biomass make 19% of the total solid biomass supplied for energy consumption. The largest reported imported feedstock is black liquor (677,404 thousand m^3). The origin of black liquor is pulp and paper industry where, for each ton of wood pulp, seven tons of black liquor are produced. Black liquor volume is high, but the feedstock is of low energy density compared to the original wood used for the pulping process. After black liquor, the category with the highest imported amount was the forestry-based biomass. Wood pellets were the most imported feedstock within the forestry-based biomass category (21,926 thousand m^3), as seen in Figure 10**Error! Reference source not found.** below. The second most imported feedstock within the forest-based biomass category was roundwood, followed by chips, saw dust, and other wood particles.

9 Information based on the biomass questionnaire as requested to MSs as part of the Governance Regulation and NECPRs. Supply of biomass - annual data https://ec.europa.eu/eurostat/databrowser/view/NRG_CB_BM__custom_6532701/default/table?lang=en

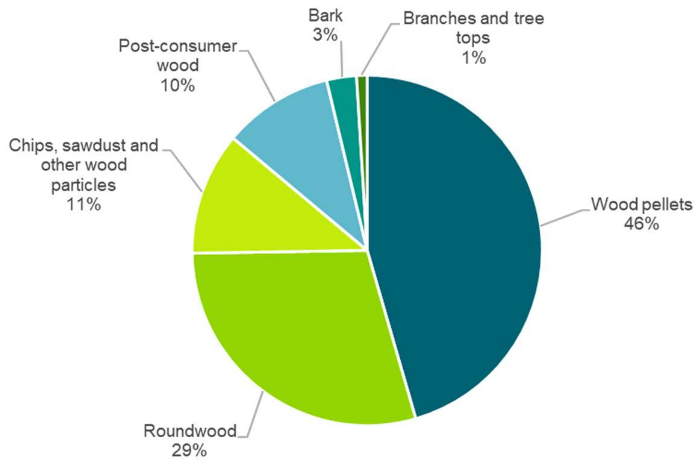

Figure 10: Feedstocks within the forest biomass used for energy production category reported as imported by EU MSs. Source: Eurostat Supply of biomass - annual data (NRG_CB_BM)

Wood pellet imports make up 42% of the total wood pellet supply for energy consumption in 2021. The total wood pellet import was 21,926 thousand m^3. Since wood pellets are a standardised type of solid biomass with known heating values, volumes traded resemble energy content with a higher precision. Figure 11 shows the Netherlands is importing nearly 30% of the total EU wood pellet imports, followed by Denmark with 26%. Denmark notes this trend in their reported measure ‘2-EN-02: Biomass Agreement’ as described in chapter 3.2. Due to data inconsistencies in the biomass questionnaire, the import of wood pellets was cross-referenced with the trade statistics from Eurostat.[10] Please note that the biomass questionnaire only covers wood pellets for energy production, while the trade statistics in Eurostat covers all import of wood pellets (noting that energy is the most common use of wood pellets). Eurostat reported that 34% of the import was by the Netherlands, 15% by Denmark, 12% by Belgium, and 8% by Latvia as the top importing countries in 2021. The Netherlands and Denmark are the two main importing countries in both datasets, although actual percentages differ.

10 EU trade since 1988 by HS2-4-6 and CN8

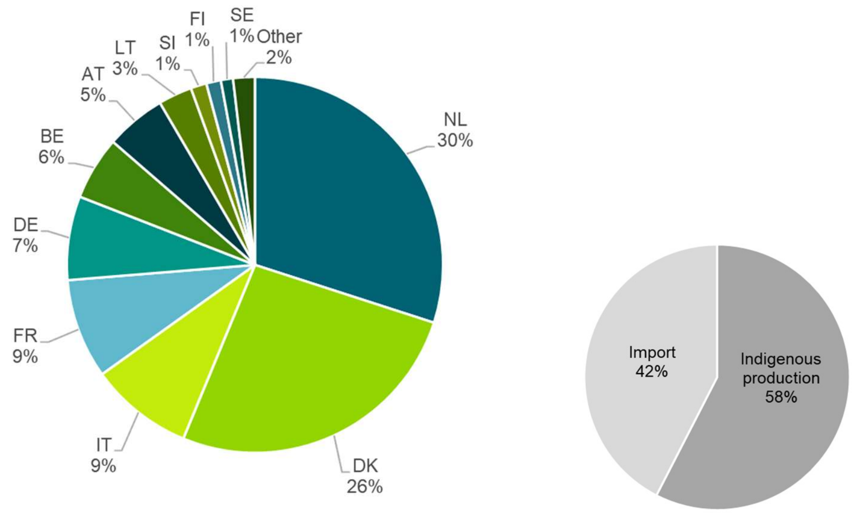

Figure 11: Wood pellet import for energy production in EU MSs in 2021 (left) and total share of import and indigenous production (right). Source: Eurostat Supply of biomass - annual data (NRG_CB_BM)

The geographic origin of the wood pellets can be traced back using the Eurostat trade balances. These are the total wood pellets imported to the EU, thus not only for energy production (but as indicated previously there are limited other uses of wood pellets besides energy). Russia was the largest exporter to the EU in 2019, 2020, and 2021, followed by the United States and Belarus. There has been an increase in wood pellet import compared to 2019 of 27%.

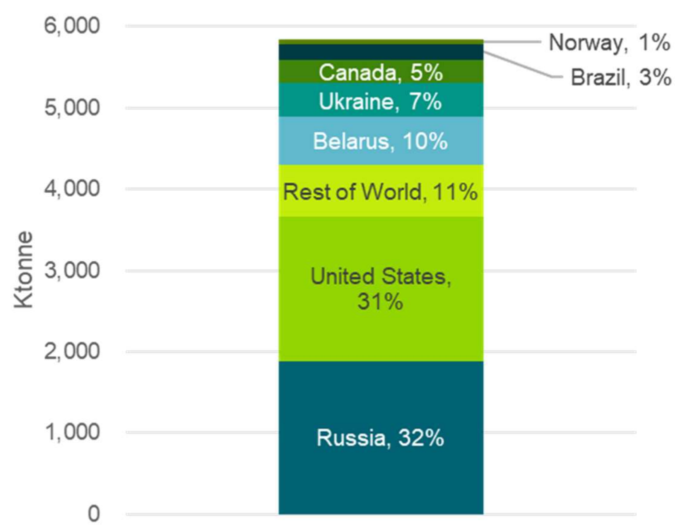

Figure 12: Geographic origin of the imported wood pellets to EU in 2021. Source: Eurostat EU trade since 1988 by HS2-4-6 and CN8

Wood chips imports make up 8% of the total wood chip supply for energy consumption in 2021 according to the biomass questionnaire data. France imported a third of the total imported wood chips volume in the EU, see Figure 13 below. Lithuania imported 22%, followed by Latvia with nearly 10% and Italy with nearly 9%.

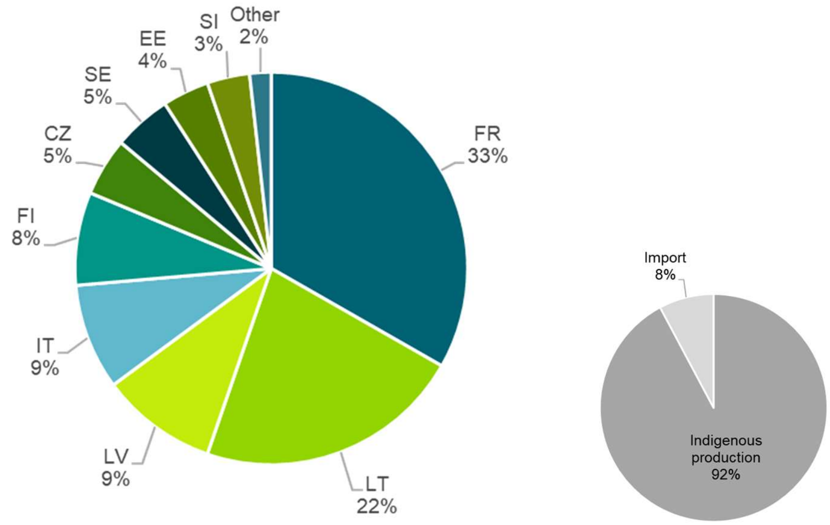

Figure 13: Wood chips import for energy production in EU MSs in 2021 (left) and total share of import and indigenous production (right). Source: Eurostat Supply of biomass - annual data (NRG_CB_BM)

The Eurostat trade statistics did not include the geographical origin of imported wood chips in 2021. However, Figure 14 below gives an overview of the geographical origin of the imported wood chips volume in 2019 and 2020. Imports from Belarus and Russia represent 82% of the total imports from the rest of the world to the EU in 2020, the remaining exporting countries are Norway (8%), Brazil (5%), Uruguay (4%), and Ukraine (2%). Contrary to the wood pellets, the reported volumes import of wood chips decreased from 2019 to 2020 by 10%. This decrease was mainly due to a decrease of import from Uruguay from 959 ktonne in 2019 to 248 ktonne in 2020.

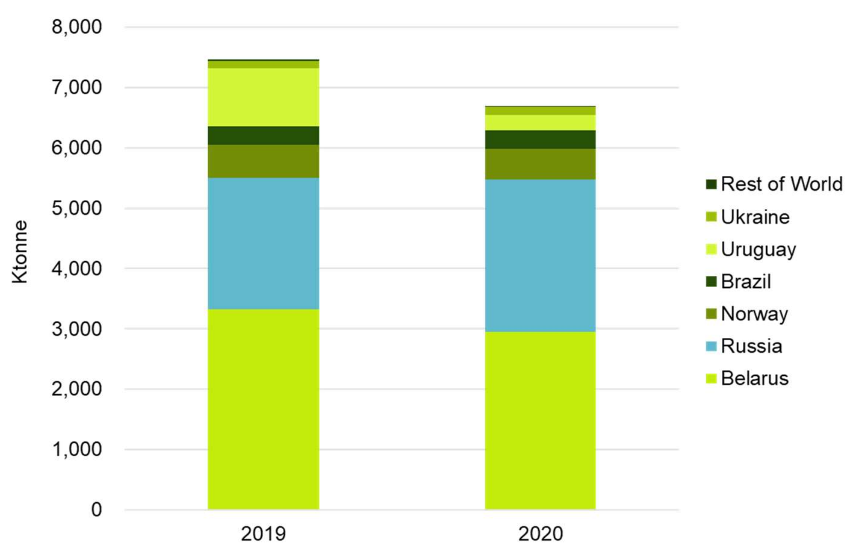

Figure 14: Geographic origin of the imported wood chips to EU in 2019 and 2020. Source: Eurostat EU trade since 1988 by HS2-4-6 and CN8

Organic waste imports represent 1% of the total organic waste supply for energy consumption in 2021. Only four MSs reported importing volumes of organic waste biomass: the Netherlands, Portugal, Sweden, and Belgium (see Figure 15 below). Sweden imports the most organic waste, namely in the form of renewable fraction of industrial waste. Additionally, Sweden is the largest importer of renewable municipal waste. The Netherlands and Belgium were the only MSs to report importing waste sludges, 56 thousand m^3 and 4 thousand m^3, respectively.

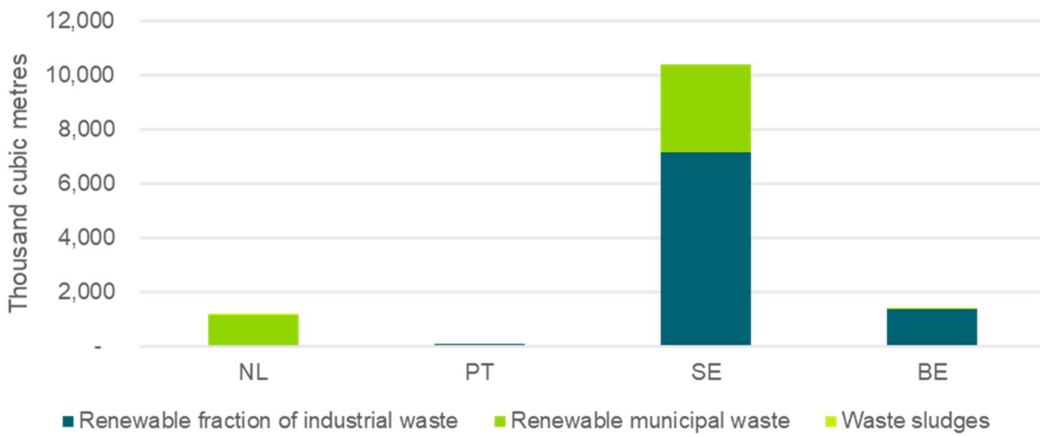

Figure 15: Imported volumes of organic waste biomass per MS in 2021. Source: Eurostat Supply of biomass - annual data (NRG_CB_BM)

Production of biogas

The indigenous[11] biogas production in 2020 and 2021 per MS based on the NECPRs is shown in Figure 16. In 2020, Germany reported the largest production of biogas with 61.6% of the total European amount produced (7,765 ktoe), followed by Italy (16.0%, 2,018 ktoe), Czechia (4.7%, 595 ktoe), and Denmark (4.0%, 505 ktoe). In 2021, the largest producer was again Germany with 58.8% (7,518 ktoe), followed by Italy (16.3%, 2,078 ktoe) and Denmark (4.9%, 625 ktoe), which overtook Czechia (4.6%, 591 ktoe) in biogas production. Belgium, Finland, Hungary, and Sweden did not report any biogas production in 2020 or 2021, whereas Estonia, Romania, and Slovenia reported biogas production in 2021, but not in the year prior. The countries whose production shrank from 2020 to 2021 were Czechia, Greece, Poland, and Latvia, who reported a joint decrease in production of 18.5%. This drop does not seem to align with their reported policy efforts related to stimulating biogas, but no further information could be found in the NECPRs. The combined EU-27 indigenous biogas production was 12,789 ktoe in 2021, a 1.4% increase with respect to 2020 (12,609 ktoe).

11 The word 'indigenous' here refers to biogas, biofuel, or biomass produced in a MS.

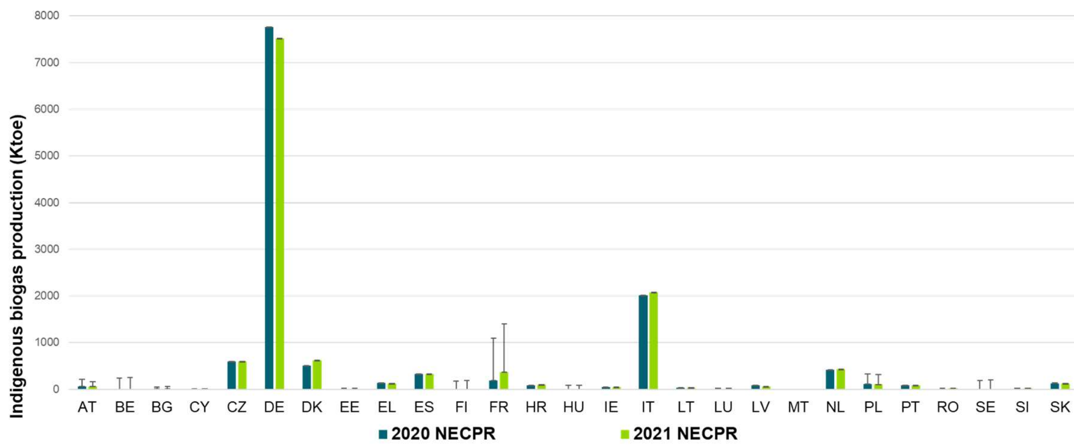

Figure 16: Indigenous biogas production in 2020 (left bar) and 2021 (right bar) per MS. The error bars visualize the difference with the values as reported in the Eurostat energy balances. Source: NECPRs and [NRG_BAL_C]

Also in Figure 16 the differences in reported values with those as reported in Eurostat are visualized as error bars to facilitate comparison. For both 2020 and 2021, the order of top biogas producing countries is not different based on this data, but their shares are. In 2020, according to the energy balances Germany produced 52.9% (7,765 ktoe) of all biogas, followed by Italy (13.7%, 2,018 ktoe), France (7.4%, 1,090 ktoe), Czechia (4.1%, 594 ktoe), and Denmark (3.4%, 505 ktoe). In 2021, according to the energy balances Germany produced 50.4% (7,518 ktoe) of total biogas, and was followed by Italy (13.9%, 2,078 ktoe), France (9.4%, 1,404 ktoe), Denmark (4.2%, 626 ktoe), and Czechia (4.0%, 591 ktoe). Combined EU-27 biogas production rose from 14,687 ktoe in 2020 to 14,929 ktoe in 2021, an increase of 1.7%.

Other significant differences between the NECPRs and Eurostat can be observed. According to Eurostat data, each MS produces biogas to some extent, even Malta with 1 ktoe. This was not the case according to the data reported in the NECPRs. Reported amounts of produced biogas also vary between sources. France's 2021 biogas production is 1,034 ktoe higher in the energy balances (1,404 ktoe) compared tothe amount reported in its NECPR (370 ktoe). For the 2020 number this difference is lower, but still considerable (900 ktoe). This discrepancy of production between the energy balance and NECPR also occurs in other MS's reporting. For Poland, the difference was 214 ktoe in 2021, and 213 ktoe in 2020; for Austria, 149 ktoe and 100 ktoe; for Bulgaria, 54 ktoe and 47 ktoe; for Estonia, 6 ktoe and 20 ktoe; and for Luxembourg, 4 ktoe and 5 ktoe, for the same years respectively. For Cyprus, the difference in both years was 8 ktoe, and in Slovakia 1, although the latter could be a rounding error.

Liquid biofuel production

The NECPRs did not contain data for liquid biofuel supply, as this is not a requirement in the Governance Regulation (EU) 2018/1999 Annex IX Part 1. The data for the following analysis has been retrieved from Eurostat [table: NRG_INF_LBPC].[12]. Liquid biofuel production capacities for 2020 and 2021 for all 27 MSs are visualized in Figure 17. Germany has reported the biggest production capacity in both years (28.7%/10,058 kton and 28.2%/10,180 kton, respectively), which was more than double that of the second reported biggest producer, Spain (13.4% in 2020 and 13.0% in 2021, 4,701 kton for both years).

12 Liquid biofuels production capacities (online data code NRG_INF_LBPC)

France reported the third biggest production capacity with a 4,000 kton capacity for both years, which represented 11.4% in 2020 and 11.1% in 2021. The following top three were the Netherlands (8.1%/2,830 kton in 2020 and 8.2%/2,967 kton in 2021), Italy (7.2% in 2020 and 7.1% in 2021, 2,544 kton for both years), and Portugal (6.4%/2,234 kton in 2020 and 7.1%/2,562 kton in 2021). The main differentiator between Germany and the others is its considerable production capacity of other liquid biofuels, particularly methanol, at 5,505 and 5,228 kton for 2020 and 2021, respectively. Five MSs (Cyprus, Estonia, Luxembourg, Malta, and Slovenia) had no biofuel production capacity in either year, whereas Croatia and Ireland had a production capacity of less than 100 kton per year. Production capacities remained the same or increased in all MSs except for Slovakia, where a 5.4% decrease occurred.

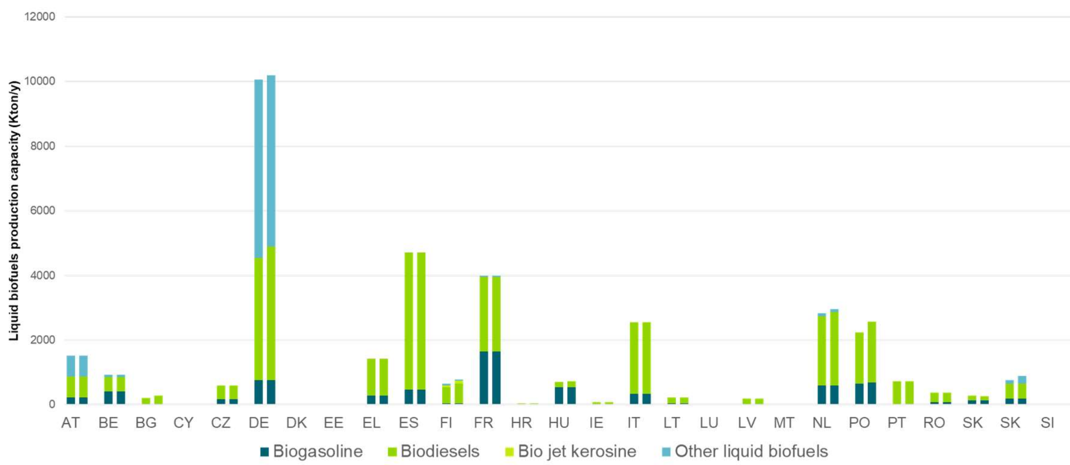

Figure 17: Liquid biofuel production capacities in 2020 (left bar) and 2021 (right bar) per MS. Source: Eurostat table NRG_INF_LBPC

The EU's overall liquid biofuel production capacity over the years is displayed in Figure 18, based on energy balances data from Eurostat. An increase in capacity for all types of liquid biofuels over the period 2008-2021 is evident: 48.5% for biodiesel, 76.4% for biogasoline, and 119.5% for other liquid biofuels. The production capacity of bio jet kerosine started to emerge in 2011 (1 kton) and rose to 89 kton by 2021. Biodiesel is the liquid biofuel with the highest installed production capacity with a share of 63.2% or a total of 22,779 kton in 2021. The installed production capacities for biogasoline and other liquid biofuels were 6,729 kton (18.7%) and 6,451 kton (17.9%), respectively.

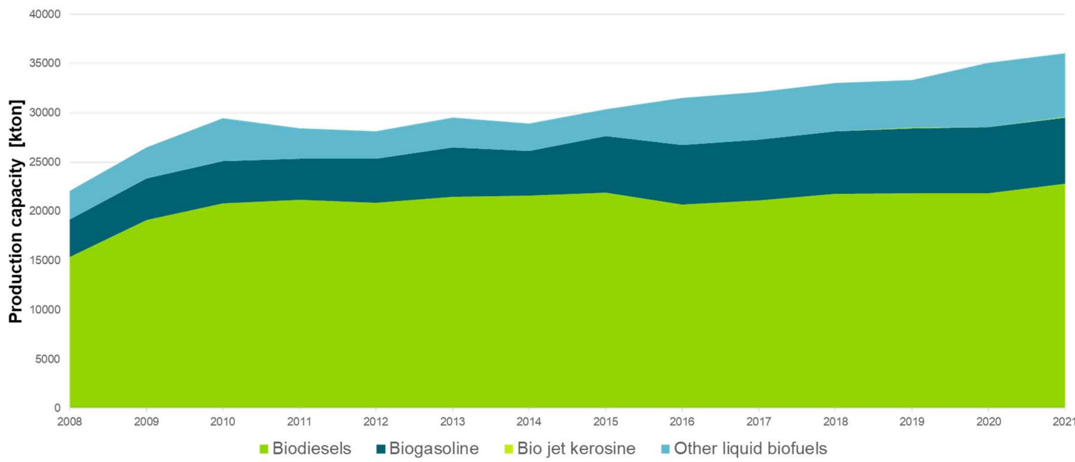

Figure 18: Total EU-27 liquid biofuel production capacity. Source: Eurostat table NRG_INF_LBPC

Geographic origin of liquid biofuels

This section estimates the geographical origin of the feedstocks used for EU-consumed biodiesel and bioethanol. The analysis combines data on the feedstocks used for biodiesel and biogasoline[13], import data of those feedstocks[14], total consumption and domestic production of biodiesel and biogasoline[15]. The analysis presents a proxy based on typical trade of these commodities to Europe.

Figure 19 below provides an overview of the proportions of the geographical origin of the feedstocks. Around half of the biodiesel (43%) and 78% of the bioethanol comes from EU production. Indonesia and Malaysia are the biggest exporters of biofuels feedstock when looking outside the EU, representing 17% of the total of biodiesel feedstock. The remaining 41% of the biodiesel feedstock imports is diversified across more than nine countries worldwide. In total, the EU imported 8,194 ktoe worth of feedstock for the biofuels market in 2021.

13 USDA: Biofuels Annual - European Union, 2022
14 Eurostat: EU trade since 1988 by HS2-4-6 and CN
15 Eurostat: Complete energy balances (NRG_BAL_C)

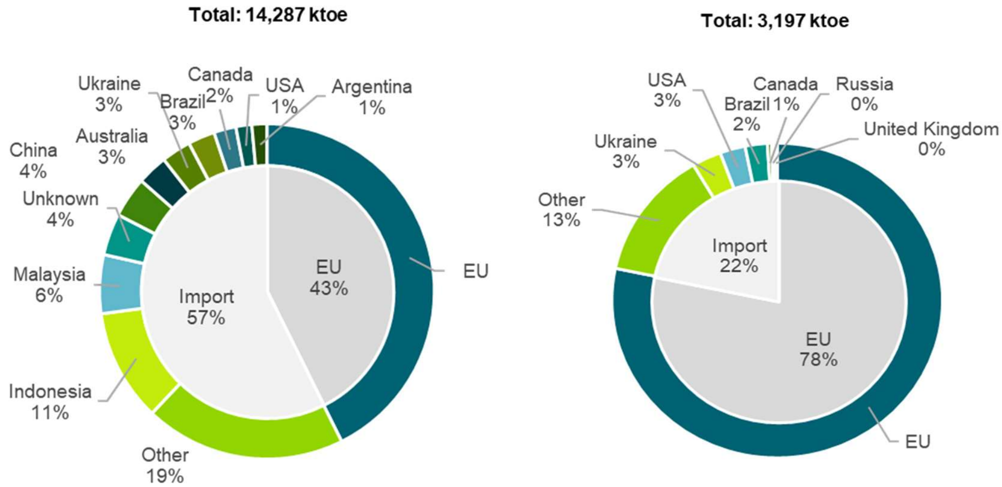

Figure 19: Geographical origin of feedstock for biodiesel (left) and bioethanol (right) for the EU in 2021. Source: Guidehouse analysis

Table 2 below provides an overview of the estimated share of the geographic origin per feedstock as a percentage of the total per that feedstock for biofuels consumed in Europe in 2021. The vast majority of rapeseed originates from the EU (77%). Indonesia and Malaysia dominate the oil palm feedstock production, which is imported into the EU, with an estimated 94% of the total oil palm consumed in the EU biofuel market in 2021 (65% Indonesia and 29% Malaysia). For soy, 13% comes from EU production, while the remainder is imported from Brazil (40%) and Argentina (18%). The Annex IX Part B feedstocks largely come from EU production, namely 44% of used cooking oil (UCO) and 100% of animal fat. 21% of the UCO used for biofuels in the EU originates from China. When looking at the common bioethanol feedstocks, the majority is almost exclusively grown in the EU, except for sugar cane, which originates from Brazil.

Table 2: Geographic origin per feedstock per country in 2021. Source: Guidehouse analysis

	Rapeseed	Palm oil	Soybean	UCO	Animal fat	Wheat	Corn	Barley	Rye	Sugar beet	Sugar cane	Cellulosic
EU	77%		13%	44%	100%	98%	84%	100%	98%	100%		100%
Argentina			18%	1%								
Australia	9%			0%								
Brazil		0%	40%				4%				100%	
Canada	5%		6%	0%		0%	1%					
China			0%	21%								
Indonesia		65%		6%								
Malaysia		29%		7%								
Other	1%	7%	1%	19%		1%	2%	0%	1%			
Russia						0%	0%		1%			
Ukraine	8%		2%	0%		0%	9%	0%	1%			
Unknown				2%					0%			
USA			21%	1%		0%						

2.2.2. Projected primary supply of biomass by feedstock and origin

This section describes relevant information related to the evolution of bioenergy supply and whether that has an impact on the overall and sectoral trajectories for renewable energy from 2021 to 2030, as reported by MSs in their NECPRs.[16] 21 MSs reported any information, of which, eight MSs[17] stated there were no significant impacts or updates to mention. Reports from the remaining 13 MS are elaborated on below.

Croatia reported negative impacts on the overall and sectoral trajectories for renewable energy because of the absence of domestic production and limited supply of advanced biofuels.

In Estonia, biomass plays an important role in the heating and cooling sector. However, they stress that possible future 'limits' on biomass consumption for this sector in the RED could present the possibility of not achieving their targets.

France did not provide detailed information beyond stating that the updates to their NECP will contribute to new trajectories of bioenergy, specifically for the agriculture, forest, and wood sectors.

Hungary recently reported a 15% increase in fuelwood supplied by state-owned forest companies, but they note that demand for fuelwood has increased considerably because of the war in Ukraine. They hope the impact on the trajectories for renewable energy are only temporary.

Italy's NECPR estimates substantial stability regarding internal solid biomass consumption between 2017-2030 with an increase even between 2020-2030. Moreover, solid biomass actual use in 2021 aligned with scenario data.

In Latvia, bioenergy supply chains were impacted in 2022 because solid biomass feedstock imports from Russia and Belarus were stopped, which led to increased solid biomass prices. However, Latvia produces more solid biomass fuel than it consumes, so although the feedstock import has reduced, the bioenergy supply remains stable.

In Lithuania, it is estimated that the scale of biomethane production limits the consumption of biomethane in stationary installations in 2030.

Malta reported that according to their 2019 NECP, that biomass consumption for heating purposes is expected to remain stable and follow current trends.

The Netherlands reported that the contribution of woody biomass in heat production will be limited to 8 PJ in 2030 due to a subsidy stop for low-temperature heat from biomass, as of April 2022.

Also related to woody biomass, Slovakia reported a downward trend of the energy use of wood biomass since 2016, mainly because of the adoption of legislative restrictions on the use of the production potential of forests, as well as restrictions on the energy use of forest biomass. Slovakia stated that the energy utilization rate of forest biomass is low (50%), leading to decreased economic efficiency of forestry and negative impacts on the forest management quality.

Slovenia reported that an increase in the use of wood biomass in the years leading up to 2030 is expected. They estimate an annual amount of low-grade wood that could be extracted from forests, corresponding to a value of 1,578,000 tonnes of dry matter and an energy value of 8.4 TWh. According to their NECP projection, current use is expected to increase to almost 1,600 GWh by 2030, which is attributable to the increased CHP use of wood biomass.

16 The NECPRs referenced look at 2020-2021 data, but several MSs also provided 2022 data.
17 The eight MSs that reported no significant impacts or updates include AT, BG, CY, CZ, DK, EL, FI, and PT.

Spain reported positive impacts on overall and sectoral trajectories for renewable energy from 2021-2030, but did not provide an explanation or further detail.

Sweden noted that although their bioenergy supply has not decreased, prices have risen as a result of the energy crisis. They further report the potential to increase the national supply of solid biomass fuels up to 40 TWh by 2030 and 53 TWh by 2045. However, the concluded that national targets could be impacted if the EU Parliament implements restrictions on forest biomass.

From the draft NECPs[18], one MS (Hungary) included bioenergy supply projections, see Table 1. Hungary reported specifically on projected capacity limits of forest firewood and other 'primary solid biomass' (for which we assume they mean primary forest biomass). These capacity limits are projected to decrease, from a total of 104 PJ in 2030 to 84 PJ in 2050.

Table 3: Projected bioenergy supply, as reported in the NECPs

MSs	Theme	Type	Unit	2030	2040	2050
Hungary	Domestic production (capacity limits)	Forest firewood capacity limit (modelled)	PJ	39	35	32
Hungary	Domestic production (capacity limits)	Other primary solid biomass capacity limit (not modelled)	PJ	65	58	52
Hungary	Domestic production (capacity limits)	Total estimated primary solid biomass capacity limit	PJ	104	94	84

2.2.3. The share of electricity produced from biomass without the utilisation of heat

MSs are requested to provide data on electricity that is produced from biomass without the utilisation of heat, based on Article 20 (a)(5) of the Governance Regulation and Annex II, Table 7, Row 7 of the IR (EU) 2022/2299. However, no MS reported any information about this topic in the NECPRs. Also, other data sources such as Eurostat Energy Balances, Eurostat SHARES, or the biomass questionnaire do no provide data on this topic.

2.2.4. Energy recovered from the sludge acquired through the treatment of wastewater

Information on the amount of energy recovered from wastewater sludge is supposed to be reported according to Article 20 (a)(5) of the Governance Regulation and Annex II, Table 7, Row 6 of the IR (EU) 2022/2299. However, most MSs did not report anything on the topic of waste sludge in their NECPRs. Four MSs (Spain, Slovenia, Finland, and Cyprus) stated that this topic is not applicable to them or that they have no related target or national trajectory. Only two MSs provided data for the amount of energy that is recovered from the sludge acquired through the treatment of wastewater: Czechia and Bulgaria. Their information is presented in Table 4.

18 Updated Draft NECP (as submitted September 13th): https://commission.europa.eu/energy-climate-change-environment/implementation-eu-countries/energy-and-climate-governance-and-reporting/national-energy-and-climate-plans_en#national-energy-and-climate-plans-2021-2030

Table 4: MSs' responses to NECPR Annex II, Table 7, row 6, on the energy recovered from the sludge acquired through the treatment of wastewater.

Member State	Description	Name of indicator to monitor progress	Unit	2020	2021
Czechia	The Energy recovered from the sludge acquired through the treatment of wastewater is being monitored and assessed but no explicit target is formulated.	Electricity and heat produced from communal and industrial wastewater treatment facilities (heat cannot be inputed due to the clasification of the indicator)	MWh	114,262	114,124
Bulgaria	There is no specific objectives.	Biogas production	ktoe	6.1	5.9

The biomass questionnaire provides data on amounts (volumes) of waste sludge that each MS indigenously produces, imports, and exports (see Section 2.2.1), but not on the amount of energy that is retrieved from this. Other data sources, such as Eurostat Energy Balances and Eurostat SHARES, do not provide any data on this topic.

2.3. Shares of current and projected bioenergy demand in quantities, types and origin, for transport, electricity and heating/cooling

2.3.1. Current and projected bioenergy demand for transport sector

Based on the Eurostat Energy Balances [table: NRG_BAL_C][19], the final consumption of biofuels in the EU transport sector[20] was a total of 16.7 Mtoe in 2021.[21] Biodiesel made up 81.2% of the total biofuel consumption in transport and is used in all EU-27 countries, which is illustrated in **Error! Reference source not found.**. Biogasoline was the second most consumed fuel type (18.0%) and is used in all EU-27 countries except for Cyprus and Malta. Biogases, other liquid biofuels, and solid biomass (in legend see 'Primary solid biofuels') combined add up to less than 1.0% of the total amount of biofuels consumed in transport and are only used in a few countries. Especially for Germany, this is remarkable considering they reported to have a high production capacity for 'other liquid biofuels', as noted in Section 2.2.1.

Eurostat Energy Balances state that Germany and France are the top biofuel-consuming countries in the EU, representing 34.5% of the biofuel market. When adding the contributions of Sweden (8.7%), Italy (8.5%), Spain (8.4%), Poland (6.7%), Belgium (4.6%), Finland (4.0%), the Netherlands (3.5%), and Romania (3.0%), 81.8% of the biofuel consumption in the EU transport sector is captured. It is worth noting that in France active stimulus is provided through policy measures for operators who release biofuels for consumption. In the biogasoline market, Germany and France account for 47.8% of the total biogasoline (e.g. bioethanol) consumption in the EU transport sector. Sweden is the main consumer of biogases for transport in absolute terms, on its own making up for 67.4% of

19 Flow 'Final consumption – transport sector – energy use' [code: FC_TRA_E]. Product codes: biodiesel [R5220P + R5220B]; biogases [code: R5300]; biogasoline [R5210P + R5210B]; other liquid biofuels [R5290]; primary solid biofuels [R5110-5150_W6000RI]. Energy Balances dataset (code: NRG_BAL_C)
20 Eurostat Energy Balances defines transport sector as: Rail + Road + Domestic aviation + Domestic navigation + pipeline transport + Not elsewhere specified (transport). See the 'Energy balance guide'.
21 In the comparison of Eurostat Energy Balances data with Eurostat SHARES data, we found a couple of small discrepancies. On aggregated EU level the differences were smaller than 5%.

the total EU biogas consumption in transport. Surprisingly, Sweden reported no biogas production, as described in Section 2.2.1. Apart from Sweden, only six other MSs (Austria, Czechia, Denmark, Estonia, Finland, and Italy) use biogas in their transport sector. This trend is reflected in reported measures from Denmark, Estonia, Finland, Italy, and Sweden related to the use of biogas in the transport section (see chapter 3.2). Romania is the only country that uses solid biomass (in legend see 'Primary solid biofuels') in its transport sector, although only 0.029 ktoe.

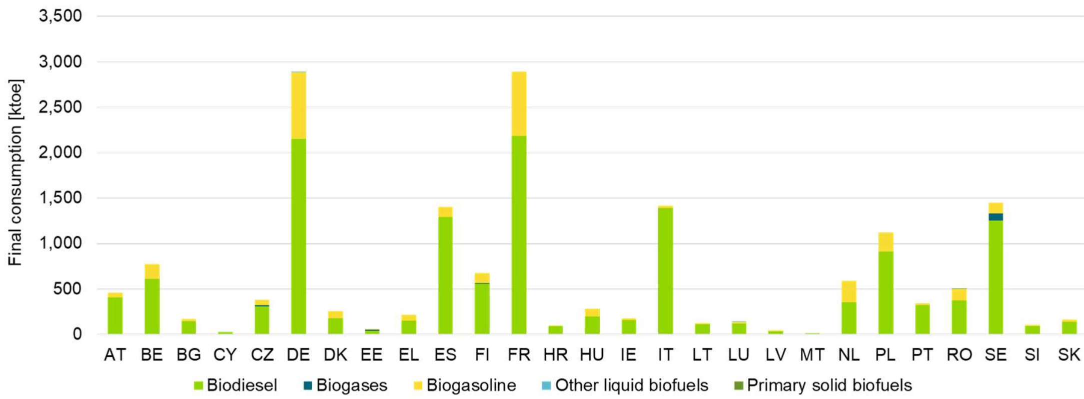

Figure 20: Final consumption of biofuels in the transport sector in 2021 per EU MS. Note that biogasoline and biodiesel include pure fuels as well as shares in blend fuels. Source: Eurostat Energy Balances table NRG_BAL_C

Over the last decade, the consumption of biofuels in the EU has increased by 39.0% from its lowest point in 2013 to its highest in 2021, as reported in the Eurostat Energy Balances. As shown in **Error! Reference source not found.**, in absolute terms, biodiesel was mainly responsible for this increase. In relative terms, however, the share of biodiesel as part of the total biofuel consumption in transport has remained quite stable at around 80.0%.

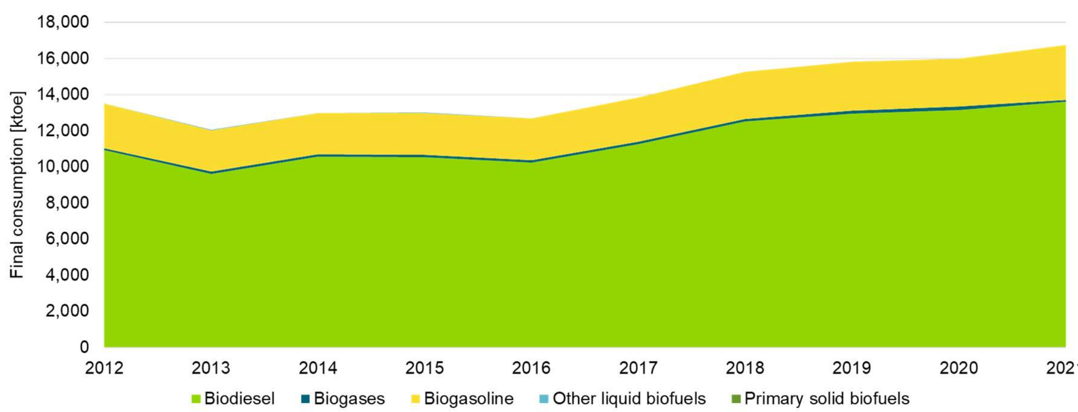

Figure 21: Final consumption of biofuels in the transport sector for EU-27 from 2012 to 2021. Note that biogasoline and biodiesel include pure fuels as well as shares in blend fuels. Source: Eurostat Energy Balances table NRG_BAL_C

Annex IX biofuels are biofuels derived mostly from waste or residue based feedstocks (see a more detailed description in section 2.5.1). Because they are mostly wastes or residues, their environmental impacts are likely to be less than the environmental impacts from traditional agricultural crops. Therefore, the use of Annex IX biofuels is encouraged. **Error! Reference source not found.** and Table 5 show the trend of Annex IX biofuel consumption from 2017 to 2021 for the EU-27 as a whole, based on the Eurostat SHARES database.

Annex IX biofuel use has seen an increase from 2,317 ktoe in 2017 to 5,474 ktoe in 2021. For all years, the consumption of Annex IX Part B biofuels is significanty higher than for Annex IX Part A biofuels. This can be explained because currently prices of Annex IX Part B biofuels are lower than most Annex IX Part A biofuels. The reason for these lower prices are, for example, that Annex IX Part B biofuels are produced through easier conversion processes, have cheaper feedstocks, and are currently more abundently available in the market.

Within the various feedstock types of the Annex IX biofuels, there are differences regarding their level of use. Consumption of biofuels based on Annex IX Part B (a), which refers to UCO, is the largest of all Annex IX feedstocks in all years to date (Figure 22 lists all Annex IX feedstocks). Within Annex IX Part A, consumption of biofuels derived from feedstocks (d) 'biomass fraction of industrial waste not fit for use in the food or feed chain' and (g) 'palm oil mill effluent and empty palm fruit bunches' is highest. Feedstock (g) has seen a significant increase since 2018. In contrast, biofuels from the following Annex IX Part A feedstocks are not used at all or used less than 1 ktoe throughout the whole EU in all considered years: (a) 'algae if cultivated on land in ponds or photobioreactors'; (l) 'nut shells'; (m) 'husks'; (n) 'cobs cleaned of kernels of corn' and; (q) 'other ligno-cellulosic material except saw logs and veneer logs'.

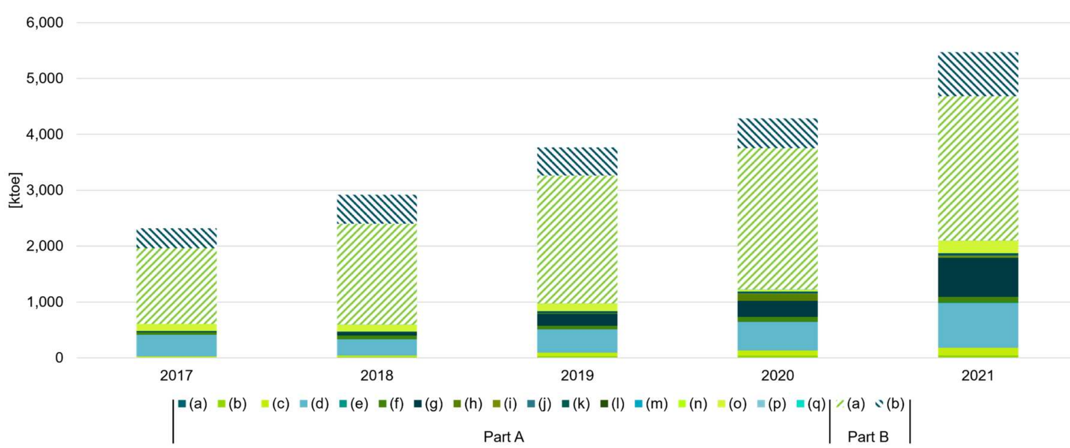

Figure 22: Trend of Annex IX biofuel demand for EU-27 from 2017 to 2021. Source: Eurostat SHARES database[22]

22 Eurostat – SHARES https://ec.europa.eu/eurostat/web/energy/database/additional-data#Short%20assessment%20of%20renewable%20energy%20sources%20(SHARES)

Table 5: Annex IX biofuel demand for EU-27 from 2017 to 2021. Source: Eurostat SHARES database

Annex IX type		2016	2017	2018	2019	2020	2021
Part A	(a)	0	0	0	0	0	0
	(b)	0	4	17	32	40	44
	(c)	21	24	24	61	94	137
	(d)	460	385	292	417	510	800
	(e)	0	0	0	0	5	9
	(f)	33	44	66	64	85	104
	(g)	3	5	49	213	285	695
	(h)	0	0	1	1	124	10
	(i)	1	2	1	9	8	27
	(j)	0	0	0	1	3	8
	(k)	17	19	21	39	32	38
	(l)	0	0	0	0	1	1
	(m)	0	0	0	0	0	0
	(n)	0	0	0	0	0	0
	(o)	52	127	124	134	34	224
	(p)	1	0	1	3	2	5
	(q)	1	0	1	0	0	0
Part B	(a)	1,074	1,354	1,803	2,288	2,527	2,580
	(b)	379	352	518	505	534	793

The consumption of Annex IX biofuels varies across MS. The use of Annex IX biofuels per MS for the year 2021 is presented in **Error! Reference source not found.** (based on the Eurostat SHARES database). It shows that Italy is the largest consumer of Annex IX biofuels with 1,339 ktoe, representing 24.4% of the total Annex IX biofuel consumption in the EU. Spain (15.8%), Sweden (11.6%), Germany (11.4%), the Netherlands (9.2%), and Portugal (4.7%) would collectively make up for 77.1% of the EU Annex IX biofuel consumption.

Italy and Spain are the largest consumers of Annex IX Part A biofuels, with the largest feedstocks being (g) ‘Palm oil mill effluent and empty palm fruit bunches’ and (d) ‘Biomass fraction of industrial waste not fit for use in the food or feed chain’. Italy, Germany, Spain, the Netherlands, and Sweden are the largest consumers of Annex IX Part B biofuels. In contrast, Romania and Latvia did not consume Annex IX feedstocks at all, and Austria consumed only a small amount (<1 ktoe). Sweden is the largest consumer of Annex IX biofuels from Part A feedstock (o), ‘biomass fraction of wastes and residues from forestry and forest-based industries‘ (85.8% of the total consumption of this feedstock is consumed by Sweden). This matches with the widespread presence of forests and related industries such as sawmills and pulp mills in Sweden.[23]

As reported in the Eurostat SHARES database, Finland used to be a large consumer of Annex IX biofuels, specifically of type Annex IX Part A (d) ‘biomass fraction of industrial waste not fit for use in the food or feed chain’. Peak consumption of this type of biofuel was 453 ktoe in 2015, but it decreased to 92 ktoe in 2021. In 2021, Finland had 501 ktoe of ‘other compliant biofuels’, so potentially a reclassification of a certain type of feedstock might explain this shift.

23 Borjesson, P., Bjornsson, L., Ericsson, K., Lantz, M. (2023). Systems perspectives on combined production of advanced biojet fuel and biofuels in existing industrial infrastructure in Sweden. Energy Conversion and Management: X. Volume 19, 100404.

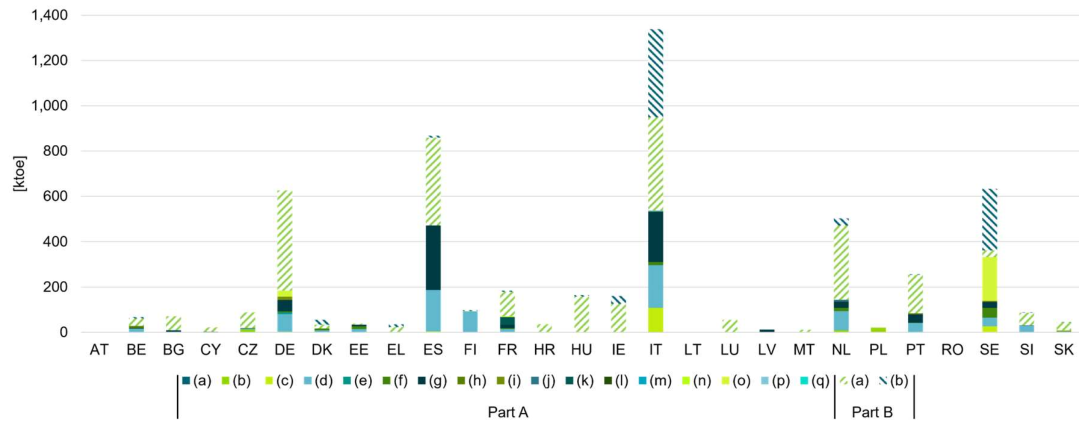

Figure 23: Split of Annex IX biofuel consumption per feedstock for each MS in 2021. Source: Eurostat SHARES database[24]

By juxtaposing the use of Annex IX biofuels with the total fuel consumption in the transport sector, the relative share of Annex IX biofuels in each MS's transport sector can be disclosed. **Error! Reference source not found.** (based on the Eurostat SHARES database) presents these shares per MS for the years 2020 and 2021, excluding the use of multipliers. Although the absolute volume of Annex IX biofuels was higher in Italy and Spain, Sweden had the highest share of Annex IX biofuels in their transport sector in 2021. Sweden had the highest share of Annex IX Part A biofuels in 2020 already, and they had a large increase in Annex IX Part B biofuels in 2021, which was a key contributor to their high total renewables in transport share.

The second highest share of Annex IX Part A biofuels is observed for Estonia, although their consumption of Annex IX Part A biofuels is relatively small in absolute terms (34 ktoe in 2021), as stated by the Eurostat SHARES database. They have the third lowest total fuel use in the transport sector and as such, a small absolute contribution of Annex IX biofuels can lead to high relative contribution.

Whereas, Italy, in absolute terms has the highest absolute demand for Annex IX biofuels (see **Error! Reference source not found.** above), in proportion, their transport sector is larger than that of other countries, according to the Eurostat SHARES database. As such, their share of Annex IX biofuels in the total transport sector is only ranked 7th and 8th highest in 2020 and 2021, respectively.

24 Eurostat – SHARES https://ec.europa.eu/eurostat/web/energy/database/additional-data#Short%20assessment%20of%20renewable%20energy%20sources%20(SHARES)

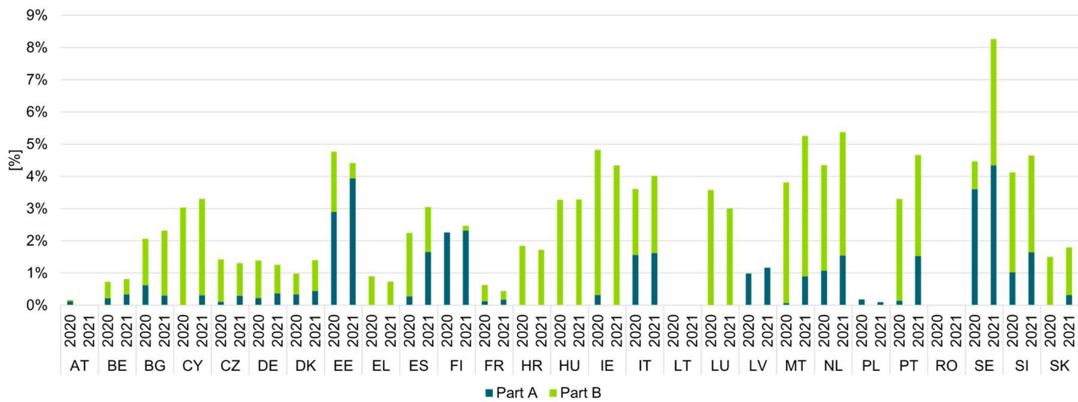

Figure 24: Share of Annex IX biofuels in transport per MS in 2020 and 2021 (excluding multipliers). Source: Eurostat SHARES database[25]

In addition to Annex IX biofuels, food and feed based biofuels also comprise part of MSs' renewable energy consumption in transport. Food and feed biofuels refer to biofuels that are produced from cereal and other starch-rich crops, sugars, and oil crops produced as a main crop (REDII Article 2(40)). For 2020, the maximum allowed contribution of food and feed crops towards the RED targets was 7%. As of 2021, the share will be capped depending on the actual share of food and feed crops in road and rail transport in 2020 per MS, plus 1%, with a maximum of 7% (so the share allowed in many MS is in reality lower than 7%). **Error! Reference source not found.** shows the share of food and feed biofuels in total fuel use in each MS's transport sector for the years 2020 and 2021 (based on the Eurostat SHARES database).[26]

The Eurostat SHARES database reports that in absolute terms France (2,562 ktoe in 2021) and Germany (2,122 ktoe in 2021) are the top two consumers of food and feed biofuels. However, due to the large total fuel use in their transport sectors, they do not have the two highest shares of food and feed biofuels in the transport sector. In 2021, Romania had the highest share with 7.3% food and feed based biofuels in their transport sector, and Belgium was second with 6.7%. Spain was a large consumer of food and feed biofuels, but their demand has declined significantly over the past few years. It saw a peak consumption of 1,737 ktoe in 2018, after which, it decreased to 693 ktoe in 2021. Similarly, Finland saw a large drop in the share of food and feed from 2020 (303 ktoe) to 2021 (65 ktoe).

25 Eurostat – SHARES https://ec.europa.eu/eurostat/web/energy/database/additional-data#Short%20assessment%20of%20renewable%20energy%20sources%20(SHARES)

26 For food and feed biofuels, the SHARES database up to 2020 referred to '3(4)d first paragraph', while the SHARES database for 2021 refers to 'Article 26(1)'. Both consider 'cereal and other starch-rich crops, sugars, and oil crops' and thus, are considered as food and feed biofuels.

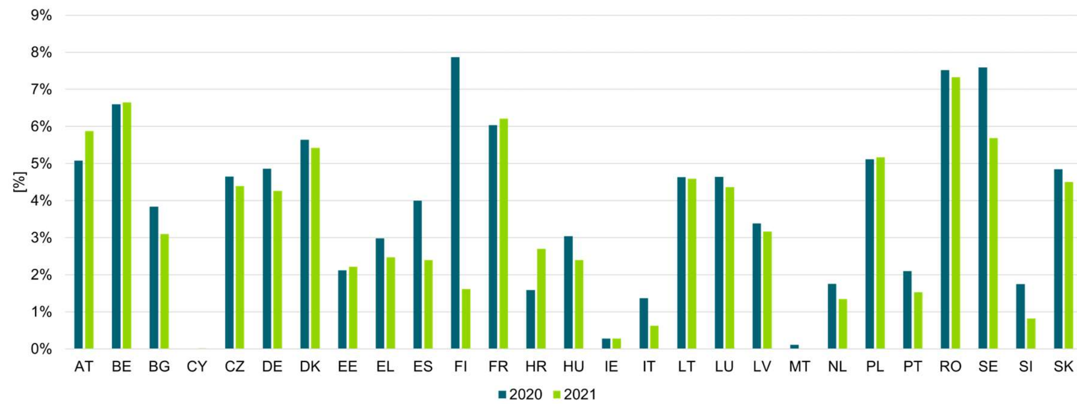

Figure 25: Share of food and feed biofuels in transport per MS in 2020 and 2021. Source: Eurostat SHARES database[27]

MS reported the renewable energy consumption in transport in the following catagories: Food and feed biofuels, Annex IX biofuels, renewable energy in road, renewable energy in rail and other transport modes and other compliant biofuels. For food and feed biofuels, MS can seperately report on the amounts of non-high ILUC fuels. **Error! Reference source not found.** outlines this share per MS for the year 2021, as reported in the Eurostat SHARES database. Note that the data is incomplete for 14 MSs. Although France used the highest absolute amount of food and feed biofuels in 2021 (2,562 ktoe), they did not provide data on amounts of non-high ILUC feedstocks. In addition, 42% of German food and feed based biofuels (second largest consumer with an amount of 2,122 ktoe), come from feedstock outside of the non-high ILUC feedstocks category. In Spain and Italy, more than 50% of food and feed-based biofuels are produced from feedstock outside the non-high ILUC feedstocks. Czechia, Latvia, the Netherlands, and Slovenia only report use food and feed biofuels based on non-high ILUC feedstocks.

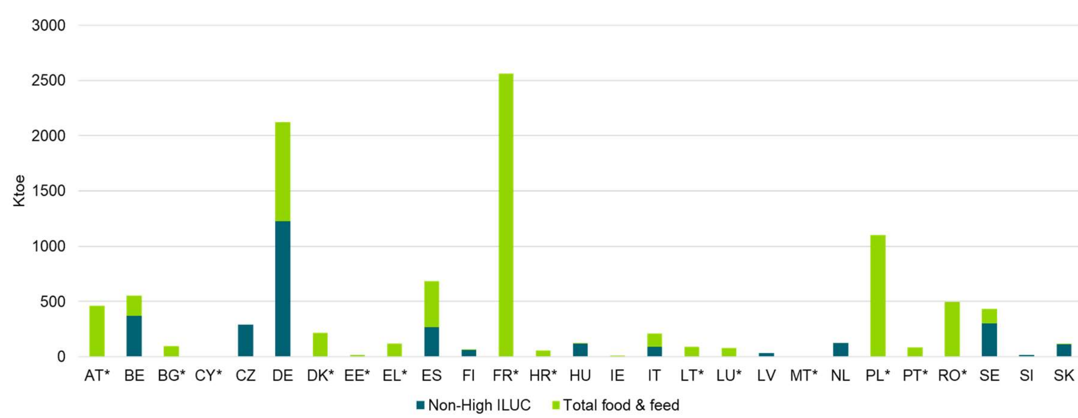

Figure 26: Non-High ILUC-risk feedstock within reported food and feed biofuels in transport per MS in 2021. Source: Eurostat SHARES database

There are various renewable energy options present in the transport sector. **Error! Reference source not found.** and **Error! Reference source not found.** show a historical overview of these renewable energy options in transport in the EU, as noted in the Eurostat SHARES database. In the calculation of the RED renewable energy targets within the transport sector, multipliers for certain fuels are taken into account. To allow for a

27 Eurostat – SHARES https://ec.europa.eu/eurostat/web/energy/database/additional-data#Short%20assessment%20of%20renewable%20energy%20sources%20(SHARES)

comparison, **Error! Reference source not found.** presents the renewable energy overview including multipliers, and **Error! Reference source not found.** excluding multipliers. The figures show that since 2011, a continuously increasing trend was present in the use of renewable energy in transport, up until 2020. In 2021, a first decrease is observed, which can be partly explained by the introduction of the REDII in mid-2021. The REDII has lower multipliers for renewable electricity in road and rail (for road 4 instead of 5, and for rail 1.5 instead of 2.5). Furthermore, the REDII introduced a cap on food and feed biofuel that is based on each MS's food and feed demand level of 2020. This cap disincentivises use of food and feed biofuels, of which, the decreasing consumption seems to be the main cause of the overall decrease of renewable energy in transport from 2020 to 2021.

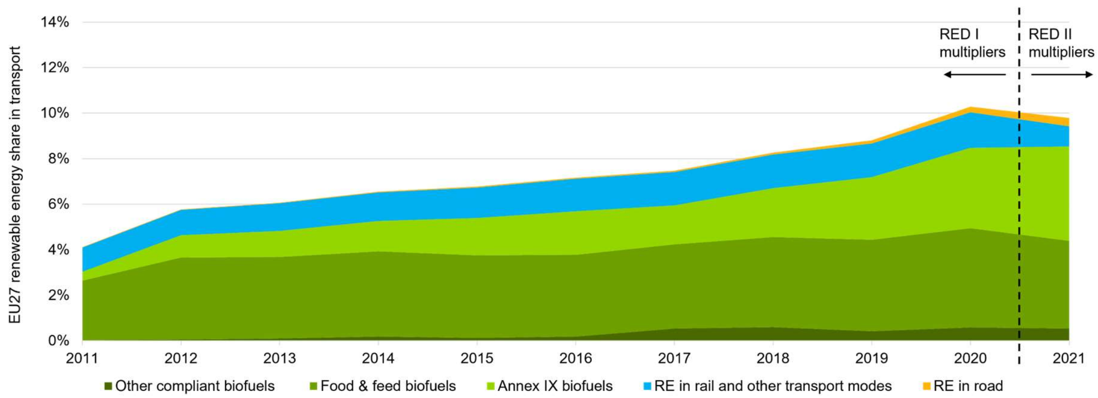

Figure 27: Historical overview of renewable energy in transport for EU-27 (including multipliers). Source: Eurostat SHARES database

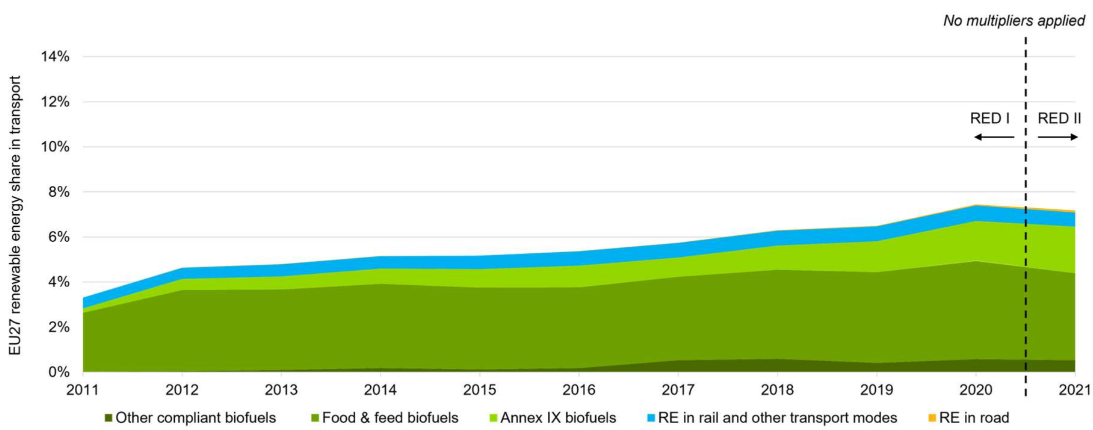

Figure 28: Historical overview of renewable energy in transport for EU-27 (excluding multipliers). Source: Eurostat SHARES database

The figures above (based on the Eurostat SHARES database) show that the current role of renewable electricity in road is still very limited at 0.36% in 2021, including multipliers (0.09% excluding multipiers). Still, in absolute numbers, it almost doubled from 120 ktoe in 2020 to 237 ktoe in 2021, so its growth is picking up. The role of renewable electricity in rail (and other transport modes) is small, but stable in the range of 1,400 to 1,600 ktoe since 2015. In 2021, renewable electricity in rail (and other transport modes) accounted for 0.9%

of the renewable energy in transport including multipliers and 0.6% excluding multipliers. The overall share of biofuels (food & feed, Annex IX, and other compliant biofuels) adds up to 6.5% of the total energy used in transport in the EU-27 in 2021. 'Other compliant biofuels' include biofuels that fulfil the sustainability criteria, but that are not from feedstocks included in Annex IX or food and feed crops. Their contribution has been in the range of 0.4% to 0.6% since 2017. When accounting for multipliers, Annex IX biofuels represent the highest share of renewable energy in transport in 2021 at 4.2%. However, when not considering the multipliers, they fall back to 2.1%, and food and feed biofuels take over as highest renewable energy contributor with 3.9%.

Currently, the NECPRs and Eurostat do not present data on projected biofuel demand for the transport sector (neither for other sectors). MSs did include projections in the draft NECP submissions. Finland, Italy, Portugal, Estonia, and Slovakia reported projected bioenergy demand in the transport sector. Italy included the REDII multipliers within their reporting, Finland and Estonia did not include these multipliers, and Portugal and Slovakia did not specify whether the reported numbers are including or excluding the multipliers. All countries expect an increase in their bioenergy consumption in the transport sector, except Slovakia for conventional biofuels which has a decrease, and Estonia projects a decrease for their generation 2 fuels. Furthermore, Estonia plans to no longer use generation 1 fuels from 2025 onwards.

Table 6: Projected bioenergy demand in the transport sector, as reported in the NECPs[28]

MSs	Theme	Type	Unit	REDII multiplier	2022	2025	2027	2030	2035	2040
Estonia	Consumption	RES-T - generation 2 fuels	GWh	excl. multipliers	723	500	340	383		
Estonia	Consumption	RES-T – including biomethane	GWh	excl. multipliers	168	144	240	383		
Estonia	Consumption	RES-T I Generative fuels	GWh	excl. multipliers	19					
Finland	Primary energy consumption	RES-T liquid biofuels	TWh	excl. multipliers	5	12	11	11		
Finland	Primary energy consumption	RES-T biogas	TWh	excl. multipliers	0.2	0.4	0.6	0.9		
Italy	Consumption	Advanced double counting biofuels *	ktoe	incl. multipliers		698		1148		1521
Italy	Consumption	Non-advanced double counting biofuels	ktoe	incl. multipliers		650		668		701
Italy	Consumption	Single counting biofuels	ktoe	incl. multipliers		325		334		350
Italy	Consumption	Advanced double counting biomethane	ktoe	incl. multipliers		313		695		1021
Portugal	Final energy consumption	Biofuels 1st generation	ktoe	unknown		33.5		40.2		
Portugal	Final energy consumption	Advanced biofuels	ktoe	unknown		293		306		
Slovakia	Consumption	Biogas	TJ	unknown		25.2		111.6	169.2	421.2
Slovakia	Consumption	Conventional biofuels	TJ	unknown		7326		7938	3214.8	2836.8
Slovakia	Consumption	Advanced biofuels	TJ	unknown				10.8	7146	17337.6

28 Updated Draft NECP (as submitted September 13th): https://commission.europa.eu/energy-climate-change-environment/implementation-eu-countries/energy-and-climate-governance-and-reporting/national-energy-and-climate-plans_en#national-energy-and-climate-plans-2021-2030

2.3.2. Current and projected bioenergy demand for heating/cooling and electricity sectors

The EU produced 14.6 Mtoe of gross electricity from biomass fuels and bioliquids in 2021, as indicated by Eurostat Enery Balances [table: NRG_BAL_C].[29, 30] This represented 5.8% of the total electricity production in the EU. Of these types of fuels, solid biomass (in legend see 'Primary solid biofuels') are the most used type (54.8%), followed by biogases (31.1%). Renewable municipal waste is responsible for 11.6%, whereas bioliquids (in legend see 'Other liquid biofuels' and 'Biodiesel') account for 2.6%. Belgium, Italy, and Slovenia are the only MSs that use minor amounts of biodiesel for electricity generation purposes (resulting in 1.1 ktoe gross electricity, combined).

Through SHARES the MSs reported a total of 93 Mtoe of renewables in their electricity sector in 2021 (37.6% of total electricity generation), to which solid biomass (excluding MSW) contributed with 7.6 Mtoe (8% of all renewables and 3% of all electricity generation). Please note that these values differ to the above since the Energy Balances present data in gross electricity produced.

Error! Reference source not found. shows that according to the Eurostat Energy Balances, Germany is the largest user of biomass fuels for electricity generation purposes. Alone, it accounts for 27.7% of the EU electricity produced from biomass fuels and bioliquids and even for 57.0% of the EU electricity produced from biogas specifically. Regarding total electricity produced from biomass fuels and bioliquids, the collective of Germany (27.7%), Italy (11.3%), Finland (8.0%), Sweden (7.7%), the Netherlands (6.4%), France (5.7%), Denmark (5.1%), Poland (4.8%), and Spain (4.1%) represent 80.8%. Finland is the largest user of solid biomass (in legend see 'Primary solid biofuels') (13.7% of EU total) for electricity generation, followed by Sweden (12.0%).

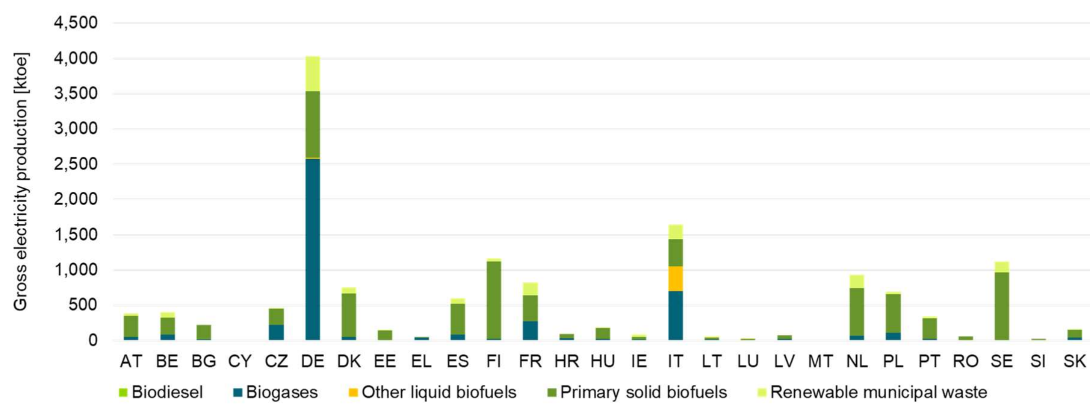

Figure 29: Gross electricity produced from biomass fuels and bioliquids in 2021 per EU MS. Source: Eurostat Energy Balances table NRG_BAL_C

Eurostat Energy Balances show that use of biomass fuels and bioliquids in electricity generation has seen a steady rise from 2012 onwards (**Error! Reference source not found.**). In 2021, production of electricity through biomass fuels and bioliquids increased by 21.5% compared to 2012. Use of solid biomass (in legend see 'Primary solid biofuels')

29 Flow 'Gross Electricity Production' (complementing indicator). This indicator includes: Main activity producer electricity only + Main activity producer CHP + Autoproducer electricity only + Autoproducer CHP. Product codes: biodiesel [R5220P + R5220B]; biogases [code: R5300]; other liquid biofuels [R5290]; primary solid biofuels [R5110-5150_W6000RI]; renewable municipal waste [W6210]. Energy Balances dataset (code: NRG_BAL_C). Please note that this indicator represents 'Transformation output' values instead of 'Transformation input' values as was the case in the Transport figure (Section 2.3.1). Hence, for electricity production this refers to the energy that is obtained from biomass fuels and bioliquids after conversion.

30 In the comparison of Eurostat Energy Balances data with Eurostat SHARES data, we found that both databases use the same values for bioenergy demand in electricity.

for electricity production was the main driver for this growth. Electricity production from solid biomass increased by 28.7% compared to 2012. In contrast, since 2017 the use of biogases reached a plateau and even saw a slight decrease.

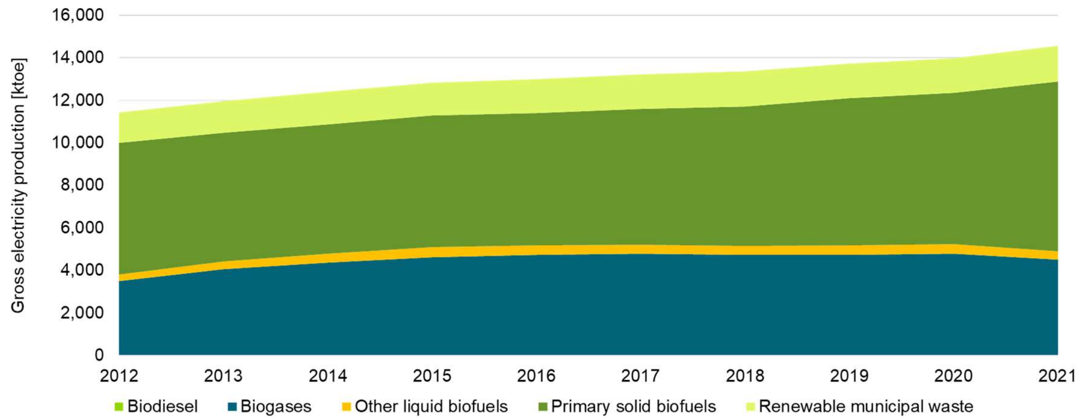

Figure 30: Gross electricity production from biomass fuels and bioliquids for EU-27 from 2012 to 2021. Source: Eurostat Energy Balances table NRG_BAL_C

In 2021, biomass fuels and bioliquids were used for the production of 17.3 Mtoe of gross heat in the EU[31,32] based on Eurostat Energy Balances [table NRG_BAL_C].[33] Eurostat Energy Balances indicates a total gross heat production of 56.0 Mtoe of which a share of 30.9% is produced from biomass fuels and bioliquids. **Error! Reference source not found.** shows that solid biomass (in legend see 'Primary solid biofuels') is the most widely used biomass fuel for heating, reaching 76.0% of the total heat production from biomass fuels and bioliquids in the EU. Renewable municipal waste comes second with 18.1% and biogases third with 5.0%.

Through SHARES the MSs reported a total of 110.5 Mtoe of renewables in their heating and cooling sector in 2021 (22.9% of 'all fuel consumed for heating and cooling), of which solid biomass including MSW was the largest renewable contributor with 88 Mtoe (80% of all renewables and 18% of all fuels consumed in heating and cooling). Please note that these values differ to the above since Eurostat presents data in gross heat produced.

Eurostat Energy Balances report that Sweden is the largest user of biomass fuels and bioliquids for heat production with 20.3% of the EU total. When also taking into account Finland (13.3%), Denmark (12.4%), Germany (10.6%), France (10.3%), Austria (6.5%), and Italy (4.9%), 78.2% of the total EU heat production based on biomass fuels and bioliquids is obtained. Sweden is also the largest user of solid biomass (in legend see 'Primary solid biofuels') for heating, alone being responsible for 20.8% of EU total. It is followed by Finland (15.8%) and Denmark (13.1%). Germany and Italy make most use of biogas in the heating sector, together accounting for 63.8% of the EU's heat production from biogas. Considering

31 Similar to our previous publication 'Technical assistance in realisation of the 5th report on progress of renewable energy in the EU', we are aware that values as presented in this Eurostat table could differ greatly in comparison with information presented by MSs in their NECPRs. This has not been analysed in detail for this report version, since no quantitative information on this is available from the NECPRs at this point in time.

32 In the comparison of Eurostat Energy Balances data with Eurostat SHARES data, we found that both databases use the same values for bioenergy demand in heat production.

33 Flow 'Gross Heat Production' (complementing indicator). This indicator includes: Main activity producer heat only + Main activity producer CHP + Autoproducer heat only + Autoproducer CHP. Product codes: biodiesel [R5220P + R5220B]; biogases [code: R5300]; other liquid biofuels [R5290]; primary solid biofuels [R5110-5150_W6000RI]; renewable municipal waste [W6210]. Energy Balances dataset (code: NRG_BAL_C). Please note that this indicator represents 'Transformation output' values instead of 'Transformation input' values as was the case in the Transport figure (Section 2.3.1). Hence, for heat production this refers to the energy that is obtained from biomass fuels and bioliquids after conversion.

the production of heat fromrenewable municipal waste, Germany is the top user with 28.9% of the total EU heat production from renewable municipal waste.

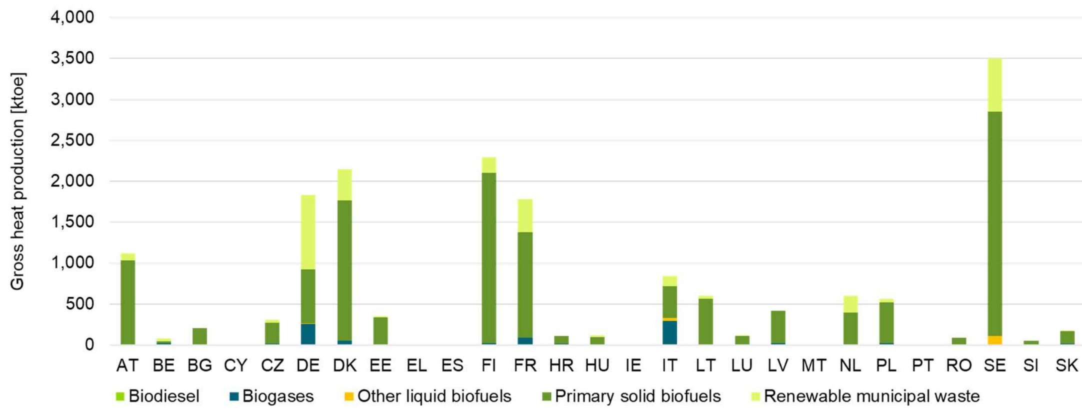

Figure 31: Gross heat production from biomass fuels and bioliquids in 2021 per EU MS. Source: Eurostat Energy Balances table NRG_BAL_C

The overall heating demand in a MS is largely dependent on their geography. **Error! Reference source not found.** presents an overview of the Heating Degree Days index based on Eurostat [table: NRG_CHDD_A][34], which provides an indication of the required amount of heating. Comparing Figure 32, the Northern European MSs (mainly Finland and Sweden) have a relatively high heating demand because they are located in a colder climate. They also have a high production of heating from biomass fuels, specifically solid biomass (in legend: ‘Primary solid biofuels’). Finland and Sweden are the top two heat producers from biomass fuels and solid biomass , which is largely a result of their high demand for heating, but also due to the large amounts of biomass available in these MSs.

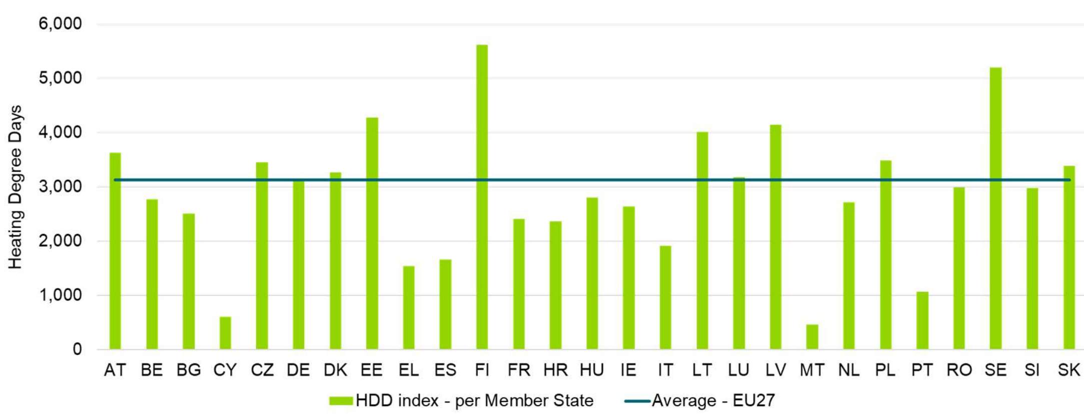

Figure 32: Heating Degree Days (HDD) per EU MS. Source: Eurostat table NRG_CHDD_A, indicator [HDD]

Similar to the transport and electricity sectors, Eurostat Energy Balances state that production based on biomass fuels and bioliquids for heating has seen a significant increase over the last decade (**Error! Reference source not found.**). 2021 observed a strong increase with a growth of 12.6% in only one year. Solid biomass (in legend see ‘Primary solid biofuels’) was the dominant fuel type responsible for this growth (similar to the

34 Cooling and heating degrees by country (online data code: NRG_CHDD_A)

electricity sector). Compared to 2012, heat production from solid biomass has grown by more than 50.0%.

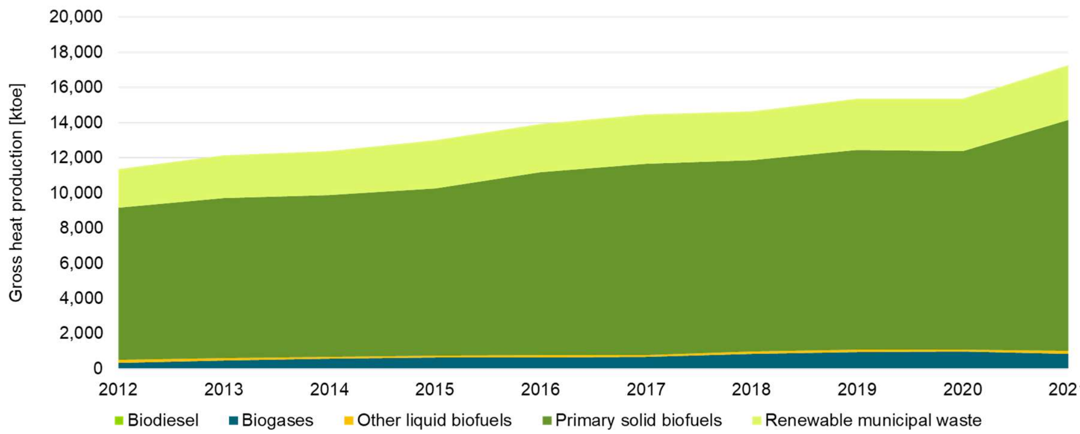

Figure 33: Gross heat production from biomass fuels and bioliquids for EU-27 from 2012 to 2021. Source: Eurostat Energy Balances table NRG_BAL_C

Currently, the NECPRs, SHARES, and Eurostat do not present data on projected biomass fuel and bioliquid demand for the heating/cooling and electricity sectors. Therefore, this section is based on the draft NECPs[35]. Six MSs reported projections for bioenergy demand in the electricity sector (Estonia, Finland, Luxembourg, the Netherlands, Spain, and Slovenia). Whereas Finland provides projections for one overall category of bioenergy demand for electricity generation purposes, the other five MSs report projections for one or multiple specific sources (e.g. biomass, biogas). Considering the heating and cooling sector, only two MSs provided projections. Finland reported data for one overall category of projected bioenergy demand in heating and cooling, while Portugal split the projections and attributed them biomass and renewable gases.

35 Updated Draft NECP (as submitted September 13th): https://commission.europa.eu/energy-climate-change-environment/implementation-eu-countries/energy-and-climate-governance-and-reporting/national-energy-and-climate-plans_en#national-energy-and-climate-plans-2021-2030

Table 7: Projected bioenergy demand in the electricity and heating & cooling sector, as reported in the NECPs

MSs	Theme	Type	Unit	2022	2025	2027	2030	2035	2040
Denmark	Consumption	Gross energy generation - Biomass-waste	GWhe		1,021		492	463	472
Estonia	Consumption	Renewable electricity production – biomass	GWh	1,400	1,540	1,540	1,540		
Finland	Primary energy consumption	RES-E Bioenergy	TWh	13	15	14	14		
Finland	Primary energy consumption	RES-H&C Bioenergy	TWh	89	92	93	93		
Luxembourg	Consumption	Domestic electricity production – Renewable waste	GWh	43	46	48	50		50
Luxembourg	Consumption	Domestic electricity production – Biogas	GWh	67	79	88	100		100
Luxembourg	Consumption	Domestic electricity production – Biomass	GWh	285	554	582	624		734
The Netherlands	Final energy consumption	Electricity and heat generation from renewable energy in buildings - biomass	ktoe		378		378	378	378
The Netherlands	Final energy consumption	Gross electricity generation - biomass-waste	GWhe		1,856		1,539	1,448	1,443
Portugal	Gross final consumption	Heating & cooling – biomass	ktoe		1,127		1,196		
Portugal	Gross final consumption	Heating & cooling renewable gases	ktoe		5		71		
Slovenia	Final energy consumption	Electricity generation from biogas	GWh		135		136	136	137
Spain	Final energy consumption	Electricity generation gross power - Biogas	GWh		1,261		2,540		
Spain	Final energy consumption	Electricity generation gross power - Biomass	GWh		4,147		6,530		
Spain	Final energy consumption	Electricity generation gross power – Waste CHP	GWh		122		84		
Spain	Final energy consumption	Electricity generation gross power – Solid urban waste	GWh		131		465		

2.3.3. Final energy consumption of solid biomass

Solid biomass is used throughout the EU in the industry, residential, and energy sectors, as presented in **Error! Reference source not found.** and based on Eurostat Energy Balances [table: NRG_BAL_C].[36,37] At the EU collective level in 2021, the industry sector consumed 21.1 Mtoe of solid biomass (8.8% of final energy consumed), the residential sector 45.2 Mtoe (17.3% of final energy consumed), and the energy sector 33.0 Mtoe (2.6% of transformation input). Germany, France, and Sweden are the top three solid biomass consumers, consuming respectively 12.3%, 10.5%, and 10.1% of the total biomass in these sectors. Malta, the smallest biomass consumer, only consumes a small amount in its residential sector (1.5 ktoe).

36 Flows 'Final consumption – industry sector – energy use' [code: FC_IND_E]; 'Final consumption – other sectors – households – energy use' [code: FC_OTH_HH_E]; 'Transformation input – energy use' [code: TI_E]. Product code: primary solid biofuels [R5110-5150_W6000RI]. Energy Balances dataset (code: NRG_BAL_C)
37 In the comparison of Eurostat Energy Balances data with Eurostat SHARES data, we found that both databases use the same values for solid biomass consumption in Industry and Residential.

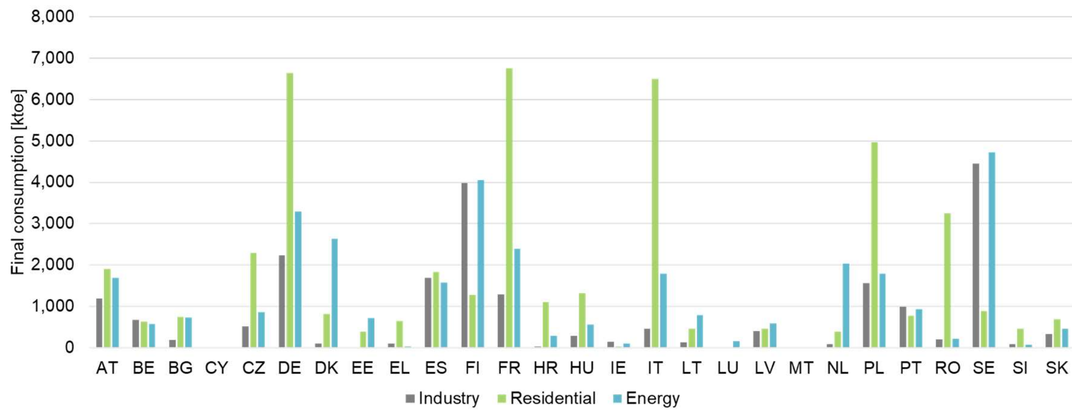

Figure 34: Final consumption of solid biomass in the industry, residential and energy sectors in 2021 per EU MS. Source: Eurostat Energy Balances table NRG_BAL_C

Final consumption of solid biomass is concentrated in the following MSs, according to the sector:

- The Energy sector uses 33.2% of the solid biomass (of the three considered sectors: industry, residential, and energy) for the total final energy consumption. Eleven MSs (Sweden (14.3%), Finland (12.3%), Germany (10.0%), Denmark (8.0%), France (7.2%), the Netherlands (6.1%), Italy (5.4%), Poland (5.4%), Austria (5.1%), Spain (4.8%), and Portugal (2.8%)) use 81.4% of the total solid biomass used by energy sector.
- The Industry sector uses 21.3% of the solid biomass (of the three considered sectors: industry, residential, and energy) for the total final energy consumption. Eight MSs (Sweden (21.1%), Finland (18.9%), Germany (10.6%), Spain (8.0%), Poland (7.4%), France (6.1%), Austria (5.6%), and Portugal (4.6%)) use 82.2% of the total solid biomass used by industry.
- The Residential sector uses 45.5% of the solid biomass (of the three considered sectors: industry, residential, and energy) for the total final energy consumption. Ten MSs (France (14.9%), Germany (14.7%), Italy (14.4%), Poland (11.0%), Romania (7.2%), Czechia (5.1%), Austria (4.2%), Spain (4.1%), Hungary (2.9%), and Finland (2.8%)) use 81.2% of the total solid biomass used by the residential sector.

Eurostat Energy Balances report that the use of solid biomass in the industry, residential, and energy sectors has increased by 13.4% compared to 2012 (**Error! Reference source not found.**). While 2012 to 2020 remained quite stable with a combined consumption of around 90 Mtoe, 2021 had an especially strong increase of 8.1% in one year, reaching a combined consumption of almost 100 Mtoe. The use of solid biomass in industry remained relatively constant, whereas energy use had the highest increase in this year with 12.3%.

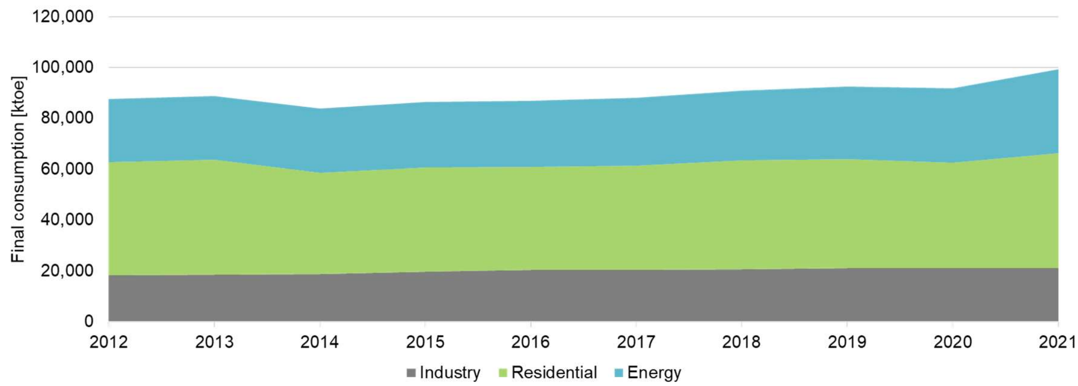

Figure 35: Final consumption of solid biomass in the industry, residential and energy sectors for EU-27 from 2012 to 2021. Source: Eurostat Energy Balances table NRG_BAL_C

This section covers projections from the NECPs[38] of four MSs that either did not specify the sector of the biomass or reported high-level consumption projections of biomass. The solid biomass gross inland consumption of Denmark is expected to decrease. In Finland, all forest-based biomass categories are expected to have an increase in primary energy consumption, except small-scale combustion of wood, pellets, etc. Slovakia projects a decrease in annual usable potential of conifers fuel biomass, but a slight increase in other forest-based biomass categories.

Table 8: Projected bioenergy demand in unknown sector, as reported in the NECPs

MSs	Theme	Type	Unit	2022	2025	2027	2030	2035	2040
Denmark	Gross inland consumption	Solid biomass	Ktoe		3884		2490	2057	1765
Denmark	Gross inland consumption	Other bioenergy (incl. biogas and biofuels)	Ktoe		3338		4559	4409	4517
Finland	Primary energy consumption	RES overall bioenergy	TWh	107	118	119	120		
Finland	Primary energy consumption	Black liquid and other concentrated liquors	TWh		46		48		
Finland	Primary energy consumption	Industrial wood residue and forest chips	TWh		49		51		
Finland	Primary energy consumption	Small-scale combustion of wood, pellets, et.	TWh		15		13		
Finland	Primary energy consumption	Waste (biodegradable fraction)	TWh		5		4		
Lithuania	Final energy consumption	Firewood	ktoe				615		567
Slovakia	Annual usable potential	Conifers fuel biomass	Thousand t		718		693		
Slovakia	Annual usable potential	Fuel biomass of leafers	Thousand t		2108		2182		
Slovakia	Annual usable potential	Fuel biomass on non-forest land	Thousand t		942		1031		

38 Updated Draft NECP (as submitted September 13th): https://commission.europa.eu/energy-climate-change-environment/implementation-eu-countries/energy-and-climate-governance-and-reporting/national-energy-and-climate-plans_en#national-energy-and-climate-plans-2021-2030

2.4. Potential impacts on commodity prices and land use associated with increased use of biomass

2.4.1. Changes in commodity prices

Currently, as shown in the data under section 2.2 part of the biofuels used are produced from food crop feedstocks. As a result, a discussion has emerged regarding the potential impact of biofuel production on the price of food crops[39]. The line of reasoning is that more biofuel production would lead to shortages in food crops, in turn, leading to higher crop prices and negatively impacting food security. This section elaborates on this potential relation by presenting 1) information provided by MSs; 2) results of a quantitative assessment, and; 3) findings from a literature search.

The full details as reported by MSs in their NECPRs (Annex XVI) on the changes in commodity prices that are associated with biomass and other forms of energy from renewable sources are presented in Annex I of this report. Nine MSs (Belgium, Bulgaria, Croatia, Denmark, Germany, Greece, Ireland, Portugal, and Slovenia) did not provide an answer to this question in the NECPR Annex. The most interesting and valuable responses are highlighted below.

Many MSs mention that commodity prices have increased over the last years, however, they do not relate this increase to increased use of biomass for energy production. Instead, MSs mention that other factors are more influential in setting the price of the commodities. Czechia, the Netherlands, Lithuania, Romania, France, and Italy explain that the geopolitical situation related to the war in Ukraine and the energy crisis has played a major factor in the commodity price increases. It should be noted that the Russian invasion happened in early 2022, and actually the latest year that is considered in the NECPR reporting is 2021. In the responses it is not clarified if the price increases have been documented before 2022 or if these are mainly related to the aftermath of the war.

Another reason mentioned by Lithuania is the trend in the global commodity markets as the driving factor of price increases in commodities. Sweden describes that high demand of energy assortments might increase prices of traditional assortments from time to time, but on the other hand, production of energy assortments generally increases profitability of forest operations and this way decreases prices of tradtional assortments. France adds that renewable fuels require energy for their production and are therefore also dependent on price variations in other sectors. In France specifically, the consumed biofuels are mainly produced from agricultural resources, of which the price is partially dependent on the oil price. For forest biomass prices, Finland describes that other industries, such as the forest industry, are a more significant factor in determining commodity prices of, for example, roundwood. Spain explains that the share of feedstocks used for bioenergy purposes are small compared to the total amount of produced feedstocks. Thus, they assess the impact of biofuel production on commodity prices as insignificant.

Cyprus and Estonia report that, in their specific cases, domestic agricultural land is not used for the production of crops used for energy purposes. Thus, they have minimal to no domestic production of biomass feedstocks produced in agricultural lands and therefore, cannot relate or separate the use of biomass for energy production and commodity prices.

In addition to the NECPR responses, a quantitative assessment of the relation between crop prices and biofuel production has been performed and is shown in Figure 36.The axis on the right depicts the global production of biofuels in a normalised manner. The axis on the left represents a global crop price index that is created by normalising and averaging

39 The Commission, as also stated in the Communication on safeguarding food security (COM (2022) 133 final), *supports Member States in using possibilities to reduce the blending proportion of biofuels which could lead to a reduction of EU agricultural land used for production of biofuel feedstocks, thus easing pressure on the markets for food and feed commodities.*

prices of commodity crops mainly used for biofuels that are available in the World Bank commodity prices overview.[40]

Error! Reference source not found. shows that both biofuel production and crop prices experienced an increase from 2000 to 2008. However, from 2008 onwards biofuel production has seen a strong growth, while crop prices remained relatively stable and even saw a slight decrease from 2011 to 2020. Thus, no immediate direct or indirect relation between biofuel production and crop prices can be derived from this quantiative perspective.

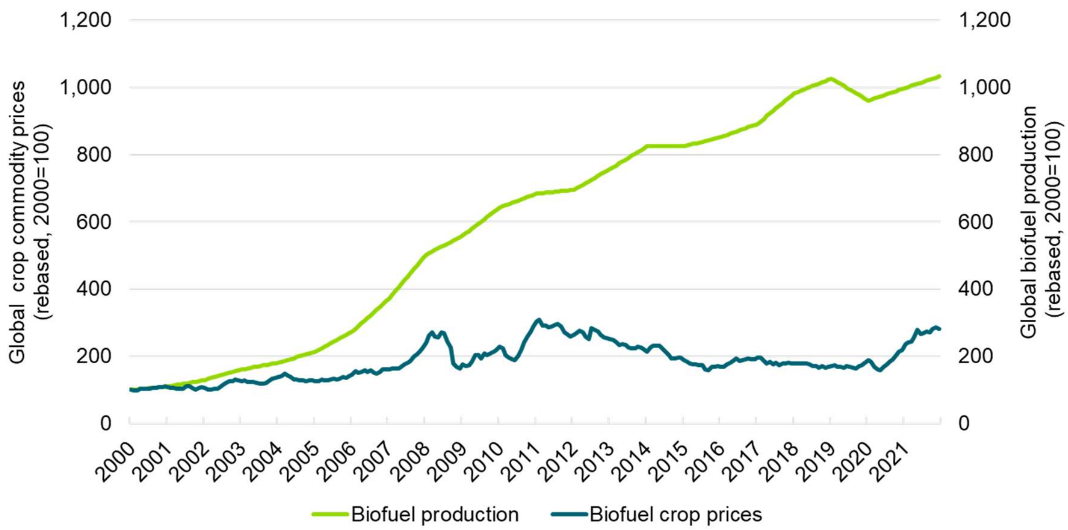

Figure 36: Aggregated price of biofuel crop commodities versus global biofuels production volume. Both vertical axes are normalised with base year 2000

In literature, studies come to mixed findings with regard to the relation between biofuel production and food crop commodity prices. The comprehensive and nuanced overview of arguments that is provided in Ecofys 2013 still holds today.[41] Data that is presented in more recent studies confirm that the direct impact of biofuel cultivation on food prices is difficult to measure[42] and continue to arrive at mixed conclusions. Certainly, the crop price to food price relation is not one-to-one, since crops need to be treated before becoming food. Furthermore, many other factors have an impact on the price of crops, for example, stocks, market dynamics, and production costs. Regarding production costs, energy prices are of significant influence. A study by Shrestha et al. (2019) found that "*Among several variables tested as a cause of food price index increase, crude oil price had the highest correlation*."[43]

Furthermore, the impact of high crop prices on the poor is ambiguous. Whereas higher crop prices lead to higher food prices, which increases cost of living and can cause food poverty, the majority of the poor works in agriculture and would potentially receive higher incomes if crop prices were to increase. Lastly, a review study of 51 countries by Subramaniam et al. (2020) on the relation between biofuels, environmental sustainabilty, and food security concludes that even though production of biofuels from crops could have a negative impact

40 World Bank, 2023. Commodity Markets – "Pink Sheet Data" – Monthly prices.
41 Ecofys. 2013. Biofuels and fuel security.
42 D.S. Shrestha, B.D. Staab, J.A. Duffield. (2019). Biofuel impact on food prices index and land use change. Biomass and Bioenergy. Volume 124. Pages 43-53. ISSN 0961-9534. https://doi.org/10.1016/j.biombioe.2019.03.003.
43 D.S. Shrestha, B.D. Staab, J.A. Duffield. (2019). Biofuel impact on food prices index and land use change. Biomass and Bioenergy. Volume 124. Pages 43-53. ISSN 0961-9534. https://doi.org/10.1016/j.biombioe.2019.03.003.

on food prices and food security in the short term, there are win-win possibilities in the long run.[44]

2.4.2. Changes in land use

This section analyses the changes in land use associated with the production of EU biofuels based on the following two types of data:

1) The data reported in the MS Progress Reports.

2) A statistical analysis: The total amount of land that is estimated to produce the feedstocks is calculated by combining the results about the type and origins of feedstocks with associated yields per country of origin and the total consumption of biofuels. This also gives insights into land used for EU biofuel consumption in the main countries of feedstock supply.

MS reports

MSs are required to report any changes in land use associated with the increased use of biomass for renewable energy. 14 MSs have filled in the appropriate field (Annex XVI, Table 2): Austria, Cyprus, Denmark, Finland, Hungary, Italy, Latvia, Lithuania, Luxembourg, Malta, Poland, Slovakia, Spain, and Sweden. All 14 MSs reported a qualitative description of potential changes, while 5 MSs (Denmark, Latvia, Lithuania, Luxembourg, and Poland) also provided quantitative data.

Denmark, Italy, and Latvia reported an increase of land area as a result of bioenergy. Denmark reported that although biogas production is relying dominantly on waste and residues, there were increases in maize growing over the eight-year period from 2,390 ha to the current 17,433 ha in 2020/2021. Italy reported land-use change but did not elaborate on the scale of the impact. Latvia reported an increase of 3.0% in 2021 compared to 2020 for cereals, but note that the change is negligible in comparison with the remaining cropland. Poland reported that in 2020 there was in estimation of 766 kha of land for bioenergy cultivation. In 2021, this increased to 797 kha.

Slovakia, Lithuania, and Finland all reported no change in land use. Lithuania reported that they were unable to assess to which extent the food and feed crops grown are for biofuels or for other markets, but estimated that the influence of the biofuel market was negligible. Finland reported no change due to low utilization of agricultural biomass for energy purposes. Finally, Slovakia did not elaborate why there were no changes.

Luxembourg was the only MS that reported a decrease of land used for energy crops. In 2018, 2.1% of the total cropland was used for energy purposes compared to 1.5% in 2022. A majority of the production for energy purposes comes from maize for biogas (67% in 2022).

The other 7 MSs (Austria, Cyprus, Estonia, Hungary, Malta, Spain, and Sweden) reported there was either no or no significant amounts of land used for bioenergy. Estonia, Hungary, and Spain did not provide information on energy crop cultivation and land use. Spain elaborated to explain this information was not available and that very little maize was used to produce bioethanol. Austria, Cyprus, and Malta reported that no energy crops were grown locally, thus no domestic land use. Lastly, Sweden reported that the minor energy crop plantations that are grown domestically are on marginal agricultural land.

Statistical analysis

Most of the feedstocks for biofuels consumed in the EU originate from food and feed crops such as sugar, starch, or oil crops (66% for biodiesel and 99% for bioethanol), out of which 57% and 22%, respectively, is imported, see Section 2.2.1. Although the consumption of

44 Yogeeswari Subramaniam, Tajul Ariffin Masron, Nik Hadiyan Nik Azman. (2020). Biofuels, environmental sustainability, and food security: A review of 51 countries. Energy Research & Social Science. Volume 68. 101549. ISSN 2214-6296. https://doi.org/10.1016/j.erss.2020.101549.

Annex IX biofuels has been increasing, according to the data presented above under section 2.3, food and feed-based biofuels are still being used. Therefore, it is important to understand how biofuel consumption in the EU impacts the land used for this part of food and feed crop production both domestically and globally. In this section, the total land use for the production of biodiesel and bioethanol as the main fuel additives/replacement to diesel and gasoline in the EU transport sector in 2021 is estimated based on statistical analysis. This estimate covers, separately, lands that are used within the EU and in third countries for the production of biofuels consumed in the EU.

To model the land use, this report applies a methodology[45] based on combining the origin of feedstocks for biofuels production (as developed in chapter 2.2.1) with country-specific crop yields.[46] The method does not deliver an exact insight into where feedstock for EU biofuels were originally produced because there are many unknowns in the supply chain. However, it can estimate land use based on market averages and provide insights into the trade of main biofuels and main feedstock.

Methodology for land use modelling

The land use for crops used as feedstock for biodiesel and bioethanol is modelled based on the types and origin of feedstock, as assessed in section 2.2.1. Land use is assessed for the most relevant crop-country combinations:

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

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

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

The modelling results indicate that out of the 8.7 Mha land used for biofuels feedstock in 2021, 4.8 Mha (56%) is located within the EU and 3.8 Mha (44%) is located outside the EU, see Figure 37. The 4.8 Mha of land used for biofuels feedstock in the EU amounts to around 4.3% of the total cropland available in the EU in 2021. When looking outside the EU, Brazil is the feedstock provider with the largest land area destined for the feedstocks for EU biofuels market with an estimate of 7.4% of the <u>total</u> land area used for cultivation of biomass for EU biofuel consumption in 2021. The main crop Brazil exported to the EU was soy. Brazil is followed by Australia (7.1% - 616 kha) and Canada (6.4% - 554 kha) for total cultivated land for biofuels that were produced or consumed in the EU in 2021. Rapeseed was the largest exported feedstock estimated from both Australia and Canada to the EU for biofuels.

45 This methodology is based on the methodology as developed by Ecofys for the use in the Ecofys report for the EC on renewable energy progress and biofuels sustainability, published in November 2014.

46 Crop yields originating from FAOstat. Allocation for co-products and multi-cropping systems were not included in this model.

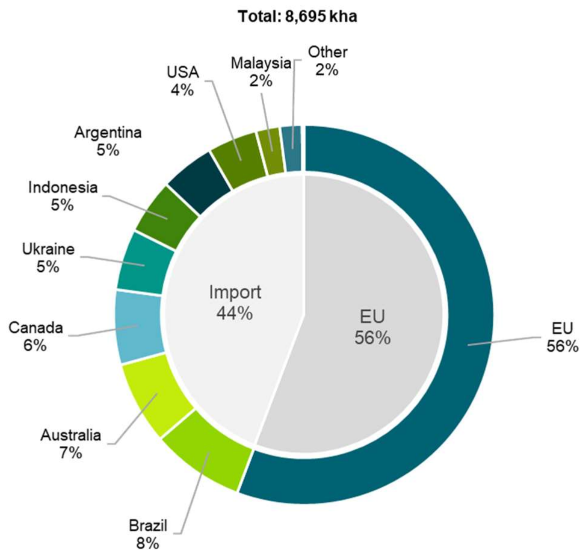

Figure 37: Total estimated area used per country for 2021 EU biofuel consumption. Source: Guidehouse analysis

Rapeseed cultivation covers the most area needed for the feedstocks considered in this analysis (53% of the total land needed in 2021 for EU biofuels consumption – 4,596 kha), most of which is domestically produced in the EU, followed by soy (21% - 1,798 kha), as is seen in Table 9. Palm oil is the food and feed crop most used as a biofuel feedstock and mainly originates from Indonesia and Malaysia. Indonesia was estimated to use 4.7% of its palm oil cultivated land for biofuels that were produced or consumed in the EU in 2021 (408 kha). This is a 0.3% increase from 2019, where it was estimated at 4.4% of the total land cultivated for biofuels for the EU biofuels market.[47]

Table 9: The share of the total estimated area that is used per country per feedstock for the EU biofuels market 2021. Source: Guidehouse analysis

	Rapeseed	Palm oil	Soybean	Wheat	Corn	Sugar beet	Rye	Barley	Sugar cane	Total (%)	Total (kha)
EU	35.9%		2.8%	5.6%	6.1%	2.8%	1.5%	1.1%		55.7%	**4,846**
Argentina			4.6%							4.6%	**401**
Australia	7.1%									7.1%	**616**
Brazil			7.4%		0.4%				0.1%	8.0%	**691**
Canada	5.1%		1.2%		0.1%					6.4%	**554**
China										0.0%	**2**
Indonesia		4.7%								4.7%	**408**
Malaysia		2.0%								2.0%	**176**
Russia				0.1%	0.1%					0.2%	**13**
Ukraine	4.1%		0.5%		0.6%					5.2%	**454**
USA			3.8%		0.4%					4.2%	**368**
Other	0.7%	0.7%	0.3%		0.2%					1.9%	**164**
Total (%)	52.9%	7.4%	20.7%	5.7%	7.8%	2.8%	1.5%	1.1%	0.1%	100%	
Total (kha)	**4,596**	**643**	**1,798**	**497**	**678**	**241**	**132**	**99**	**10**		**8695**

47 Values for 2019 were estimated based on a similar analysis based on FAO data for those years.

2.5. Technological development and deployment of Annex IX biofuels

In this section, the technological development and deployment of Annex IX biofuels is discussed. A brief description of the Annex IX biofuel production technologies that are currently being used on a (semi)- commercial scale is provided in Annex II of this report. Current deployment and production capacities within different MSs are discussed, followed by a presentation of insights on recent and planned developments in the production of Annex IX biofuels.

2.5.1. Introduction to Annex IX biofuels

Annex IX biofuels are based on biomass feedstocks listed in Annex IX of the REDII, which are mainly wastes and residues. Two categories of Annex IX feedstocks are specified, Part A and Part B. A list of the feedstocks included in Annex IX is presented in Table 10. Biofuels based on Part A feedstocks are defined as advanced biofuels.

Table 10: Description of Annex IX feedstocks

Annex IX Part	Reference	Feedstock description
Part A	(a)	Algae if cultivated on land in ponds or photobioreactors
	(b)	Biomass fraction of mixed municipal waste, but not separated household waste subject to recycling targets under point (a) of Article 11(2) of Directive 2008/98/EC
	(c)	Biowaste as defined in point (4) of Article 3 of Directive 2008/98/EC from private households subject to separate collection as defined in point (11) of Article 3 of that Directive
	(d)	Biomass fraction of industrial waste not fit for use in the food or feed chain, including material from retail and wholesale and the agro-food and fish and aquaculture industry, and excluding feedstocks listed in Part B of this Annex
	(e)	Straw
	(f)	Animal manure and sewage sludge
	(g)	Palm oil mill effluent and empty palm fruit bunches
	(h)	Tall oil pitch
	(i)	Crude glycerine
	(j)	Bagasse
	(k)	Grape marcs and wine lees
	(l)	Nut shells
	(m)	Husks
	(n)	Cobs cleaned of kernels of corn
	(o)	Biomass fraction of wastes and residues from forestry and forest-based industries, namely, bark, branches, pre- commercial thinnings, leaves, needles, tree tops, saw dust, cutter shavings, black liquor, brown liquor, fibre sludge, lignin and tall oil
	(p)	Other non-food cellulosic material
	(q)	Other ligno-cellulosic material except saw logs and veneer logs
Part B	(a)	Used cooking oil
	(b)	Animal fats classified as categories 1 and 2 in accordance with Regulation (EC) No 1069/2009

Annex IX feedstocks are a promising source for biofuels due to a variety of reasons. Firstly, their use has a high potential for the reduction of GHG emissions. Secondly, they are not associated with the risk of indirect effects on land use change, as they do not originate from food or feed crops and often do not require the use of (additional) land (e.g., they originate from processing residues and wastes). Because of these advantages, the use of Annex IX biofuels is encouraged, as they receive special treatment when used to achieve the REDII's specific renewable transport targets. The REDII specifically promotes the use of advanced biofuels with the following provisions:

- Biofuels produced from Annex IX Part A feedstocks will have a share of at least 0.2% of final energy consumption in the transport sector in 2022, rising to 1% in 2025 and 3.5% by 2030.
- The use of Annex IX-based biofuels may be double counted towards a MS renewable transport target.
- Like other fuels that are not based on food and feed crops, the share of non-food and feed crop-based Annex IX fuels used for the aviation and maritime sectors may be counted 1.2 times.

Furthermore, the REDII caps conventional biofuels based on food and feed crops as it directs that the deployment of biofuels based on these feedstocks in transport should be limited and shall be no more than 1% higher than the share of such fuels in the final consumption of energy in the road and rail transport sectors in 2020 in that MS, with a maximum of 7% of final consumption of energy in the road and rail transport sectors in that MS.[48]

2.5.2. Technological development and deployment of Annex IX biofuels as reported by Member States

An overview of the amounts of Annex IX biofuels used in transport as reported by the MSs in their NECPRs is provided in Table 11. Only five MSs (Denmark, Spain, Ireland, Italy, and Luxembourg) have reported use data in their NECPRs. They have done so in different units and not all for the same years, which makes comparison difficult. Other MSs have reported consumption data as part of their SHARES reporting via Eurostat instead, which is discussed in Section 2.3 of this report. Except for Luxembourg, which imports all of its biofuels, all of the MSs included in this table that deploy biofuels in transport also produce Annex IX biofuels. Denmark's absolute use of Annex IX biofuel increased by 37.7% from 530 TJ in 2020 to 730 TJ in 2021, whereas Luxembourg's relative use decreased from 3.5% of the overall fuel pool in 2020 to 3.1% in 2021. Spain, Ireland, and Italy only reported their 2021 use in the NECPRs.

48 MSs can set a lower target "taking into account best available evidence on ILUC impact" and differentiate by crop type.

Table 11: Overview of Annex IX biofuel deployment in transport as reported by MSs in NECPRs

Member State	Annex IX biofuel deployment in transport	Unit	Year	Annex IX Feedstock(s) used
DK	730	TJ	2021	
	530	TJ	2020	
ES	850,715	toe	2021	A - g) POME
				B - a) UCO
IE	93	% of biofuel supplied to the market	2021	
IT	5,700	TJ	2021	A - b) OFMSW
				A - f) Animal manure and sewage sludge
LU	3.1	% of overall fuel pool		'Mainly part B'
	3.5	% of overall fuel pool		

The only MSs that filled in the quantitative table were France and Slovakia. Some MSs (Denmark and Italy) only provide information on the amount of Annex IX biofuels consumed in transport in TJ, whereas others only mention annual production volumes in toe (Spain) or percentages (Ireland and Luxembourg).

An overview of the amounts of Annex IX biofuels used in transport as reported by the MSs in their NECPRs is provided in Table 12. Again, the units in which production is reported, as well as the year for which this is reported differ per MS.

Table 12: Overview of Annex IX biofuel produced as reported by MSs in NECPRs

Member State	Annex IX biofuel production capacity	Unit	Annex IX biofuel produced	Unit	Year	Annex IX Feedstock(s) used
CZ	Refers to SHARES				2019	B - a) UCO
DK	Not mentioned					A - c) Biowaste
						A - d) Biomass fraction of industrial waste
						A - f) Sewage sludge
ES	Not mentioned					A - g) POME
						B - a) UCO
FI	Same as before					
FR	677	ktoe	316	ktoe		A - d) Biomass fraction of industrial waste
						A - g) POME
						A - k) Grape marcs and wine lees
						A - l) Nut shells
						A - o) Biomass fraction of forestry and forest-based residues
						B - a) UCO
						B - b) Category 1 and 2 animal fats
IE	200,000,000	L			2021	A - d) Biomass fraction of industrial waste
						B - a) UCO
						B - b) Category 1 and 2 animal fats

Member State	Annex IX biofuel production capacity	Unit	Annex IX biofuel produced	Unit	Year	Annex IX Feedstock(s) used
IT	345	kton				A - g) POME
						A - d) Biomass fraction of industrial waste
						B - a) UCO
						B - a) Animal fats
NL	1,032	kton				
PT	32,023	m3				A - f) Sewage sludge
						A - g) POME
						A - i) Crude glycerin
						A - d) Biomass fraction of industrial waste
RO	50	kton			2022	A - e) Straw
SK	41	ktoe	32.4	ktoe	2022	B - a) UCO

Overall, it is hard to gain insights based on the information in these two tables as data is missing, fragmented, or inconsistent. Most MSs have not reported on amounts of Annex IX fuel used or produced in their NECPRs, and units and years for which data is provided differ per MS. Recommendations on how to improve this for future reporting will follow later in this report in chapter 5.

When compared to the literature study on recent developments in Annex IX biofuel production within MSs in section 2.5.3, one major discrepancy stands out: Portugal's reported production. Portugal was not known to produce Annex IX biofuels before. Furthermore, no recent technological developments in Annex IX biofuel production were found in literature and none were reported 2021's *Assessment of Member States' reports for the year 2020 final report* and 2020's *Technical assistance in realisation of the 5th report on progress of renewable energy in the EU*.[49] However, there are biorefineries in Portugal that produce hydrotreated vegetable oil (HVO) from palm oil, so it could be that Annex IX feedstocks have recently been introduced to these production facilities.[50] The other countries included in Table 12 were known to already produce Annex IX biofuels. Technological developments have recently taken place in most of them or are planned for the near future, Denmark being the only exception.

2.5.3. Recent and planned developments in EU Annex IX biofuel deployment per Member State

This section provides an overview of biorefineries that have started producing Annex IX biofuels since October 2020.[51] Most information is based on the BIKE D3.1 report[52] and supplemented with additional sources where necessary.

Bulgaria

Eta Bio is planning to open a bioethanol plant based on agricultural residue feedstock with an annual production capacity of 50,000 tons. The sunliquid® technology licensed from

49 Guidehouse. (2022). Assessment of the Member States' reports for the year 2020. [Assessment of Member States' reports for the year 2020 final report - Publications Office of the EU (europa.eu)].
50 United States Department of Agriculture. (2020). Portugal Biofuels Policy and Market. https://www.fas.usda.gov/data/portugal-portugal-biofuels-policy-and-market
51 This was when the previous version of this report was published titled '*Technical assistance in realisation of the 5th report on progress of renewable energy in the EU*.'
52 BIKE. (2021). Overview on biofuels production facilities and technologies in Europe. [20210914_BIKE_D3.1_4.0_REC.pdf (bike-biofuels.eu)]

Clariant will be used to produce cellulosic ethanol from 250,000 tons of wheat straw.[52,53] The plant commissioning date could not be readily identified.

Finland

In late 2020, Green Fuel Nordic Oy opened a HVO plant in Lieksa with an annual production capacity of 24,000 tons using woody biomass, such as sawmill by-products, as feedstock.[54] Technology was provided by BTG Bioliquids. Fintoil opened an HVO-producing biorefinery in the port of Hamina Kotka in late 2022 using Neste's NEXPINUS™ technology with a feedstock capacity of 200,000 tons of crude tall oil.[55] BioEnergo is planning to open Annex IX-based biofuel production plants in the near future.[52]

Nordfuel is planning to open a biorefinery in Haapavesi with a production capacity of 65,000 tons of bioethanol per year between 2024 and 2026 based on forest residues and sawmill by-product feedstocks.[56,57]

France

TotalEnergies announced in 2021 that it had started producing SAF via HVO in its La Mède biorefinery based on animal fats, UCO, and other wastes and residues.[58] The plant's reported annual production capacity is 100,000 tons.[59] TotalEnergies is also in the process of converting their Grandpuits refinery so that it can produce SAF via HVO from animal fats and UCO. It is expected to become operational in 2024 with an annual production capacity of 120,000 tonnes.[52]

Bionext, together with a consortium of research providers, technology providers, and industrial players, completed a testing programme on a demonstration scale (60 tons per year) of SAF via a Fischer-Tropsch process named BioTfueL.[60] TotalEnergies has also started production using this lignocellulosic biomass-based process in Dunkirk on an 8,000 tons per year scale.

Italy

Versalis, a subsidiary of ENI, started Annex IX-based bioethanol production at its plant in Crescentino in 2022, with a production capacity of 25,000 tons per year.[52] The process uses non-food and waste lignocellulosic biomass as a feedstock.

The Netherlands

UPM plans to open a 500,000 tons/y HVO plant in Rotterdam, which is estimated to start in late 2023.[61] Feedstocks to be used are forest by-products and oil from the *Brassica Carinata* crop. Furthermore, Neste is planning to expand its HVO plant in Rotterdam and reach a

53 Clariant. (2020). Clariant and Eta Bio announce license agreement on sunliquid® cellulosic ethanol technology in Bulgaria. https://www.clariant.com/en/Corporate/News/2020/07/Clariant-and-Eta-Bio-announce-license-agreement-on-sunliquid-cellulosic-ethanol-technology-in-Bulgar.
54 BTG Bioliquids. (n.d.). A true trailblazer. https://www.btg-bioliquids.com/plant/green-fuel-nordic-lieksa-finland/.
55 Fintoil. (n.d.). Fintoil. https://fintoil.com/en/biojalostamo/.
56 Nordfuel. (n.d.). NordFuel Oy. https://nordfuel.fi/en/nordfuel-oy-eng/.
57 European Investment Bank. (2019). NORDFUEL BIOREFINERY SECOND GENERATION BIOFUELS. https://www.eib.org/en/projects/all/20190298.
58 Rigzone. (2021). TOT Starts Making Sustainable Aviation Fuel in France. https://www.rigzone.com/news/tot_starts_making_sustainable_aviation_fuel_in_france-13-apr-2021-165144-article/.
59 Argus. (2021). Total starts biojet production at La Mede biorefinery. https://www.argusmedia.com/en/news/2203248-total-starts-biojet-production-at-la-mede-biorefinery.
60 Digital Refining. (2021). Successful advanced biofuels production from woody biomass on demonstration units. https://www.digitalrefining.com/news/1006430/successful-advanced-biofuels-production-from-woody-biomass-on-demonstration-units.
61 Industry & Energy. (2022). UPM chooses Rotterdam for construction of biorefinery. https://www.industryandenergy.eu/chemcycling/upm-chooses-rotterdam-for-construction-of-biorefinery/

100% feedstock share of waste and residues by 2025.[52] The current production capacity of 100,000 tons/y will be upgraded to 500,000 tons/y.[62]

OCI plans to convert its former BioMCN methanol plant in Delfzijl, which ceased production last year due to increased gas prices, to a biomethanol one. The envisioned production capacity is 450,000 tons per year and the plant will use municipal organic wastes as feedstock.[63] GIDARA Energy announced its plans for Advanced Methanol Amsterdam in 2021, which will produce biomethanol from non-recyclable municipal solid waste. The production capacity will be 87,500 tons per year and the plant is expected to open in 2023.[64] More recently, plans for a similar plant to be constructed in the port of Rotterdam were announced with an expected date of production in 2025.[65]

The EemsGas project (formerly known as Torrgas Delfzijl) aims to construct a plant that produces biomethane from wood residues, agricultural residues, manure, and sewage waste.[66] A final investment decision is expected before summer 2023.

SkyNRG plans to open an Annex IX-based biorefinery in the port of Amsterdam in 2025, which will process waste and residue streams such as UCO and animal fats into SAF (100,000 tons/y), as well as bioLPG (15,000 tons/y) and renewable Naphtha (20,000 tons/y).[67,68]

Norway

Project Silva Green Fuel, a joint venture between Statkraft and Sødra, has led to the opening of a demonstration plant that produces biofuels (diesel, jet, or marine) from forest residues via HVO.[52] An official opening was scheduled for 2021, but no information was found on whether this happened.

Nordic Electrofuel AS is planning to open a plant in Porsgrunn in 2025, which will use a Fischer-Tropsch process to turn waste gasses from cement and metal production or waste incineration into synthetic fuels with a production capacity of 25,000 tons per year.

Poland

PKN Orlen has multiple plans for new Annex IX-based biorefineries. In Plock, they aim to complete the construction of a 300,000 tons per year HVO plant utilizing rapeseed oil and UCO in 2024.[69] Furthermore, they plan to build a bioethanol plant in Jedlicze with an annual production capacity of 25,000 tons, using cereal straw as a feedstock. The plant will deploy Valmet technology.[52**Error! Bookmark not defined.**, 70]

Romania

62 Trinomics. (2022). Analyse overgang sturen op CO2. https://open.overheid.nl/documenten/ronl-964ad8890a6709e3a1c80e1b5264405254c2fda8/pdf.
63 Petrochem. (2023). OCI wil methanol uit afval produceren in Delfzijl. https://petrochem.nl/2023/04/13/oci-wil-methanol-uit-afval-produceren-in-delfzijl/.
64 Port of Amsterdam. (2021). Fabriek die niet-recyclebaar afval omzet in methanol vestigt zich in Amsterdamse haven. https://www.portofamsterdam.com/nl/nieuws/fabriek-die-niet-recyclebaar-afval-omzet-methanol-vestigt-zich-amsterdamse-haven.
65 Offschore Energy. (2022). Gidara Energy sets up Advanced Methanol Rotterdam facility. https://www.offshore-energy.biz/gidara-energy-sets-up-advanced-methanol-rotterdam-facility/.
66 Gasunie. (2022). Eemsgas. https://www.gasunie.nl/en/projects/eemsgas.
67 SKYNRG. (2019). SKYNR, KLM ans SHV Energy launch 1t sustainable kerosene factory. https://skynrg.com/skynrg-klm-and-shv-energy-announce-project-first-european-plant-for-sustainable-aviation-fuel/.
68 Demoplants21. (n.d.). https://demoplants21.best-research.eu/projects/info/3846/8JBaZy.
69 Petrolplaza. (2021). PKN ORLEN to produce innovative biofuel component. https://www.petrolplaza.com/news/28374.
70 Biofuels Central. (2022). Valmet will Deliver Key Technology Areas for ORLEN Planned Second Generation Bioethanol (B2G) Plant in Jedlicze, Poland. https://biofuelscentral.com/valmet-orlen-second-generation-bioethanol-b2g-plant-jedlicze-poland/.

As announced in the previous reporting period, Clariant completed the construction of a 50,000 tons per year bioethanol plant, which uses cereal straw as a feedstock in 2021.[71]

Slovakia

Enviral is currently upgrading its existing Leopoldov plant so that it can produce 50,000 tons of bioethanol from agricultural residues per year.[72,73]

Spain

Repsol plans to open a biomethanol plant in El Morell, which will use a gasification process based on municipal solid waste. It is expected to start operating in 2026 with a production capacity of 240,000 tons per year and will use technology provided by Enerkem.[74]

Sainc Energy Limited was planning to construct a bioethanol plant with a production capacity of 150,000 tons per year based on olive tree residues as a feedstock, but the planned project has been put on hold for unknown reasons.[52,74]

Sweden

Preem's Lysekil refinery started processing sawdust and agricultural residues to produce Annex IX Part A-approved pyrolysis oil using HVO in 2021.[75] The eventual aim is for this plant to produce 1,300,000 tonnes per year.[52] Their pyrolysis facility in Gävle also become operational in the same year, processing 40,000 tons of dry wood per year. Furthermore, Preem is has expanded the production capacity of its HVO diesel and plant in Gothenburg to 1,300,000 tons per year. It uses oil crops, oils, and fats as feedstocks.[76]

St1 is currently also constructing a biorefinery to produce HVO diesel and SAF from tall oil and UCO in Gothenburg with a capacity of 200,000 tons. The aim is for it to become operational during 2023.[77,78]

Södra opened the world's first commercial biomethanol plant in Mönsterås in 2020. The plant uses forest residues as feedstock and has an annual production capacity of 5,250 tons.[79]

Summary table

Table 13: Overview of Annex IX biorefineries per country. Data from REDII's ANNEX III was used to calculate the production capacity in MJ. The energy content for HVO meant for petrol replacement was used in case the end use of the produced HVO is unknown, as it represents a median value for all different HVOs in Annex III

71 Clariant. (2022). Clariant produces first commercial sunliquid® cellulosic ethanol at new plant in Podari, Romania. https://www.clariant.com/en/Corporate/News/2022/06/Clariant-produces-first-commercial-sunliquid-cellulosic-ethanol-at-new-plant-in-Podari-Romania.
72 Demoplants21. (n.d.). https://demoplants21.best-research.eu/projects/info/3799/8JBaZy.
73 The Digest. (2021). The Digest's Exclusive Q&A with Clariant/ Enviral: Decarbonization, EU transport, Slovakia project, biofuels developments and more. https://www.biofuelsdigest.com/bdigest/2021/03/10/the-digests-exclusive-qa-with-clariant-enviral-decarbonization-eu-transport-slovakia-project-biofuels-developments-and-more/.
74 Repsol. (n.d.). Ecoplanta: A project for municipal solid waste recovery. https://www.repsol.com/en/sustainability/circular-economy/our-projects/chemical-waste-recovery/index.cshtml.
75 Oil & Gas Journal. (2021). Preem's Lysekil refinery producing renewable fuel via coprocessing. https://www.ogj.com/refining-processing/refining/article/14210395/preems-lysekil-refinery-producing-renewable-fuel-via-coprocessing.
76 Fuels and Lubes. (2021). Preem completes revamp of Gothenburg refinery. https://www.fuelsandlubes.com/preem-completes-revamp-of-gothenburg-refinery/.
77 Demoplants21. (n.d.). https://demoplants21.best-research.eu/projects/info/3842/8JBaZy.
78 St1. (2021). SCA ans St1 enter joint venture to produce and develop liquid biofuels. https://www.st1.com/sca-and-st1-enter-joint-venture-to-produce-and-develop-liquid-biofuels.
79 Bioenergy International. (2020). Södra first in the world with fossil-free biomethanol. https://bioenergyinternational.com/sodra-first-world-fossil-free-biomethanol/.

Country	Plant operator	Plant location	(Expected) start of operations	Biofuel type	Production capacity [kt]	Production capacity [MJ]
Bulgaria	Eta Bio		Unknown	Bioethanol	50	1,350,000,000
Finland	Green Fuel Nordic Oy	Lieksa	2020	HVO	24	1,080,000,000
	Fintoil	Hamina Kotka	2022	HVO	Unknown	Unknown
	BioEnergo	Unknown	Near future'	Various	Unknown	Unknown
	Nordfuel	Haapavesi	Between 2024-2026	Bioethanol	65	1,755,000,000
France	TotalEnergies	La Mède	2021	HVO (SAF)	100	4,400,000,000
		Grandpuits	2024	HVO (SAF)	120	5,280,000,000
		Dunkirk	Unknown	Fischer-Tropsch (SAF)	8	352,000,000
Italy	Versalis (ENI)	Crescentino	2022	Bioethanol	25	675,000,000
The Netherlands	UPM	Rotterdam	Late 2023	HVO	500	22,500,000,000
	Neste	Rotterdam	2011 (current capacity)	HVO	100	4,500,000,000
			2023 (after upgrade)	HVO	500	22,500,000,000
	OCI	Delfzijl	Unknown	Biomethanol	450	9,000,000,000
	GIDARA Energy	Amsterdam	Sometime in 2023	Biomethanol	87.5	1,750,000,000
		Rotterdam	2025	Biomethanol	87.5	1,750,000,000
	EemsGas	Delfzijl	Unknown	Biomethane	Unknown	Unknown
	SkyNRG	Amsterdam	2025	HVO (SAF)	100	4,400,000,000
				BioLPG	15	690,000,000
				Naptha	20	No energy content available in Annex III

Country	Plant operator	Plant location	(Expected) start of operations	Biofuel type	Production capacity [kt]	Production capacity [MJ]
Norway	Nordic Electrofuel AS	Porsgrunn	2025	Fischer-Tropsch (SAF)	25	1,100,000,000
Poland	PKN Orlen	Plock	2024	HVO (diesel+SAF)	300	13,200,000,000
		Jedlicze		Bioethanol	25	675,000,000
Romania	Clariant	Podari	2021	Bioethanol	50	1,350,000,000
Slovakia	Enviral	Leopoldov	Unknown	Bioethanol	50	1,350,000,000
Spain	Repsol	El Morrell	2026	Biomethanol	240	4,800,000,000
Sweden	Preem	Lysekil	2021	HVO	1300	58,500,000,000
		Gothenburg	2021	HVO	1300	57,200,000,000
	St1	Gothenburg	2023	HVO (diesel+SAF)	200	8,800,000,000
	Södra	Mönsterås	2020	Biomethanol	5.25	105,000,000

3. Measures taken by Member States for the purpose of ensuring the sustainability of bioenergy

MSs are required to report on the measures they have implemented to promote the use of energy from biomass, including the sustainable biomass availability, as well as measures for the sustainability of biomass produced and used (Article 20(b)(8) of the Governance Regulation). This information could be used to provide insights for the EC to assess whether MSs are on track with and have fully enabled their planned deployment of bioenergy, as well as whether the biomass used is compliant with the sustainability criteria as agreed upon on the European level.

All MSs submitted Annexes IX to XIV on ReportNet. Together, they submitted 3,245 policies and measures in Annex IX 'PaMs attributes and progress'. These do not all relate to biomass/bioenergy and many fall outside of the scope of this project, thus a filtering method was applied to only analyse those relevant.

The filter was applied to whether one of the following fields of Annex IX (as submitted in ReportNet) contained the word *"bio"*: Field 3 (Title), Field 7 (Short Description), Field 12 (Quantified Objectives), Field 13 (Assessment Of The Contribution), Field 15.c (Relevant Provisions), Field 19.b (Explanation), Field 20 (Progress), and Field 23 (General Comments). This resulted in 459 PaMs, which have been added to one clear overview for further analysis, presented in the following sections.

3.1. Summary of Member State measures

This section provides an overview of the main types of biomass- and bioenergy-related measures reported by MSs. Measures can be either directly related or indirectly related to bioenergy. Indirectly related bioenergy measures include measures that are only broadly related to bioenergy and may, for example, include a more general focus on renewable energy sources. Indirect measures are indicated as such.

The relevant measures are organized by sector, feedstock, fuel, and measure type; however, due to the nature of the measures, overlap and inter-linkages between the topics are prevalent. There is also an overview section related to sustainability criteria, ILUC-risk crops, and fraud.

Overview of measures by measure type

Specific measure types are commonly used to promote the use of energy from biomass. These measure types are categorized into the following: regulatory/legislative changes, strategies, financial incentives, including CAPEX[80] subsidies, support schemes, and grants, and obligations.

Regulatory/legislative changes or adaptations include the various ways in which MSs apply or integrate EU regulations at the MS-level. In the measures applied across the MSs, regulatory/legislative changes refer to implementation of the NECPs or various EU directives, namely Directive 2015/1513, as well as Directive 2009/28 and its recast 2018/2001. Regulatory/legislative changes also include Royal or Government Decrees, Ministerial Orders, Agreements, or Amendments. Furthermore, some MSs[81] make note of individual measures that contribute to their national long-term strategy (as set out in Regulation EU/2018/1999).

MSs also employ **strategies**, which are not necessarily legally binding, but provide an outline on how the MS plans to promote biomass for energy purposes. An action or policy

80 CAPEX refers to capital expenditures.
81 These MSs include BG, DK, EL, ES, HR, PL, PT, SE, and SK.

plan used or developed by a MS are examples of types of strategies. Some MSs reported measures related to a waste management strategy, of which some elaborate beyond landfill and waste reduction to include biogas production. Cyprus' National Municipal Waste Management Strategy, as an example, consists of a package of measures with a dual purpose on reducing biodegradable waste and producing biogas for electricity and thermal generation. National forestry plans are also implemented to stimulate the availability of feedstocks and production of fuels. In addition, strategies focused on innovation, research, and development to modernize existing plants, improve production technology, and/or support the development of bioenergy fuels are common.

Financial incentives, **grants**, **CAPEX subsidies**, and **support schemes** are forms of financial support MSs use to incentivize bioenergy. The main objective of most of the financial support measures is to promote the end use and consumption of bioenergy, however, the focus on fuel type and sectors varies. Stimulating the production of fuels is also a common objective of these support measures. Some measures give specific details on the way in which the financial support is to be used. For example, a reported measure from Sweden outlines a support scheme for the production of biogas from manure to be used as vehicle fuel or to generate electricity or heat. However, a lot of the reported measures do not provide this level of detail or specificity.

Finally, **obligations** indicate binding targets and can include general sector targets and/or explicit targets on the use or production of bioenergy from specified fuels. The most common obligation measures introduce new or updated biofuel blending obligations in the transport sector. 22 MSs reported such an obligation.[82] Many of these obligations require biofuels to meet sustainability criteria, as they are often implemented in compliance with the REDI or the REDII. The supply or consumption of biomethane gas is also covered under some obligation measures, while others specify targets for the share of biodiesel and bioethanol. Ireland also reported an obligation measure, but it is related to the share of renewable energy, including biomass, in the heating sector.

Overview of measures by sector

Transport sector-related measures are mostly included as part of obligation measures. For more information, see the section above.

Many measures also pertain directly to the **heating and electricity sectors**. To begin, the installation of biomass/biogas plants or systems is promoted for electricity generation and/or heating purposes in 24 of the MSs that reported.[83] Five reported measures provide support specifically for innovation or technological renewal of biomass/biogas plants, one each in Greece, Italy, Portugal, Spain, and Slovenia. Regarding biogas-related measures for heating and electricity purposes, production is often associated with waste, most commonly manure or biodegradable municipal waste. The use of waste as a feedstock for biogas production serves a dual purpose: methane emissions or landfill reduction and stimulation of the production of fuels. Moreover, cogeneration heat and electricity systems for electricity generation are often supported, as well as biomass boilers using forest biomass as a feedstock for heat generation.

In Italy the production of advanced bioliquids made from waste, agricultural residues, and algae for electricity generation were incentivized until the end of 2022 under Ministerial Decree 2/3/2018.

Overview of measures by fuel and/or feedstock type

82 The 22 MSs that reported an obligation measure in the transport sector include Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Greece, Hungary, Italy, Latvia, Lithuania, Luxembourg, Malta, Romania, Slovakia, Slovenia, Spain, and Sweden.

83 The 24 MSs that reported a measure related to biomass/biogas plants in the heating and/or electricity sectors include Austria, Belgium, Croatia, Cyprus, Czechia, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden.

11 MSs[84] reported on **forest biomass**, mostly related to electricity, energy, and/or heat generation. When a measure specified the feedstock beyond the broad category of wood or forest biomass, it was commonly wood pellets or wood chips. Among the reported forest biomass-related measures, only one Spanish measure promotes energy from (forest) biomass, in which sustainability criteria are explicitly mentioned. Other reported forest biomass-related measures did not include mention of sustainability criteria. Moreover, two (indirect) measures from Spain, which are more generally focused on sustainable forest management and maintaining and improving forest reserves, are related to the LULUCF sector. Additionally, no MSs reported anything specific about challenges related to forest biomass availability in the measures they currently submitted.

Data on forest biomass policies related to the installations is rather limited, as most measures address the promotion and use of forest biomass for electricity and heat generation more broadly. However, a few measures are important to mention. In Estonia, subsidies are available for producers who generate electricity from (forest) biomass. To promote the use of wood chips, a Finnish measure offers electricity producers a production subsidy for electricity plants in the approved feed-in tariff system. In addition, a reported measure from Portugal promotes local-scale biomass-based electricity generation alongside improvements to their forest management. Regarding larger installations, Slovenia reported a measure that invests in wood biomass co-firing to modernize the combined heat and electricity units. Moreover, a measure from Spain outlines programs for the development of biomass, especially of forestry and agricultural origin, for use in the electricity and heating sectors, which includes financial aid programs for biomass boilers in the residential, commercial, and industrial sectors, as well as the use of biomass in public facilities.

Blending mandates and quotas for **advanced biofuels** are reported in some measures, particularly in the transport sector. For example, Croatia reported two measures on advanced biofuels, both of which are planned for 2023. One measure supports the development of the advanced biofuels market and includes conditions for monitoring the sustainability and GHG savings. The other Croatian measure promotes the production of advanced biofuels from residues of agricultural production and energy crops. Denmark reported a blending mandate measure for advanced biofuels, which has been fixed at 0.3% of the 7.6% total for biofuels since 2021. France also reported incorporation rates of advanced biofuels released for consumption in the transport sector until 2028. In Germany, a GHG quota is reported, which includes a support program for advanced biofuels. The measure was implemented in 2020, but details provided are limited. Moreover, in Italy, a 2020 Ministerial Decree updated the minimum percentages of advanced biofuels of the obligation to release for consumption until the end of 2022. Luxembourg implemented an obligation measure in 2022 to incorporate sustainable biofuels into road fuels and specifically also sets targets for the contribution of advanced biofuels (and biogas) in the transport sector produced from feedstocks listed in Annex IX, Part A. In Malta, as of 2021 until 2030, advanced biofuels must contribute to at least 3.5% of the 14% share of renewable energy sources supplied in the transport sector for final consumption. Slovenia also reported a measure that will increase the share of advanced biofuels from feedstocks listed in Annex IX, Part A in the transport sector; it is planned to start in 2023. A mandatory blending of advanced biofuels into motor fuels was implemented in Slovakia in 2019. Lastly, Spain reported various measures related to advanced biofuels. For example, a biofuel quota obligation was implemented in 2019 until 2030, which includes advanced biofuels with limitations on UCO and ILUC raw materials. Two separate measures (both implemented in 2021 until 2030) support advanced biofuels production installations to accomplish consumption objectives either in the aviation sector or maritime transport sector.

84 These 11 MSs include Belgium, Denmark, Estonia, Finland, France, Ireland, Luxembourg, Portugal, Romania, Slovenia, and Spain.

The promotion of advanced biofuels is also relevant outside the transport sector. Greece and Portugal also reported measures related to the development of advanced biofuels more generally, including infrastructure developments and research of advanced biofuels.

Only four MSs (Bulgaria, Cyprus, France, and Italy) make explicit mention of **conventional biofuels** in their reported measures, which generally include an introduction or description of the limits or ceilings placed on or replacement of conventional biofuels.

Biogas is promoted across various industries including electricity, transport, energy and heating, industry and agriculture, and waste (listed in order from high to low frequency). 24 MSs reported a measure related to biogas.[85] As previously stated, waste is a common feedstock as indicated in the reported measure for biogas production for electricity generation. Additionally, Denmark, Estonia, Finland, France, Germany, Greece, Italy, Lithuania, Luxembourg, the Netherlands, Slovakia, Spain, and Sweden reported at least one measure each that specifies the use of biogas/biomethane as a vehicle fuel. In some of these measures, biomethane is not explicitly listed.[86]

For example, the two Danish measures both promote biogas as fuel in the transport sector. In Finland, a measure supports biogas filling stations in road traffic as of 2018. Additionally, another Finnish measure extended the obligation legislation for compliant fuels to include biogas in 2022. Germany reported a measure that includes increasing the share of vehicles powered by biogas under the Climate Protection Program 2030. In the reported measure from Greece, the aim of the measure is to promote innovative technology in the transport sector, including developing advanced gaseous biofuels from sustainable biomass. In two (indirect) Lithuanian measures, there is support for the development of refuelling infrastructure for alternative fuels, where biogas is listed as an example. In the Netherlands, bio-LNG is promoted in freight transport under a subsidy scheme. Biogas produced from waste is promoted for use in the transport sector in Slovakia. In Spain's Biogas Roadmap measure, biogas and biomethane are planned to contribute to its renewable energy targets in the transport sector. Also, Sweden reported a measure entitled 'Support for biogas production' that promotes biogas production from manure to be used as a vehicle fuel (or to generate electricity or heat).

Some MSs, including Denmark, France, Hungary, Italy, Luxembourg, Portugal, Spain, and Sweden, reported at least one measure each promoting or regulating the injection of renewable gas, namely biogas/biomethane, into the natural gas grid. These measures are discussed in further detail in section 3.2.

Additionally, Denmark, Portugal, and Spain each reported a measure to promote biogas/biomethane in the industrial sector. The development and production of biogas related to the agricultural sector is reported in measure(s) from Denmark, Finland, Italy, Lithuania, and Poland, but the measure reported by Denmark expired as of 2015. Finally, the following MSs report at least one measure each related to biogas/biomethane and waste management (including wastes as a feedstock, especially manure): Belgium, Croatia, Cyprus, Finland, Greece, Italy, Latvia, Lithuania, Luxembourg, Slovakia, Slovenia, Spain, and Sweden. For example, one measure in Lithuania provides investment support for developing biomethane gas production and/or biogas purification plants to treat biological waste.

CAPEX subsidies, financial incentives, support schemes, strategies, and regulatory/legislatives changes are also commonly used measure types for promoting and incentivizing **biomethane** (in all sectors) across 12 MSs.[87] Estonia, France, Greece, Italy, Lithuania, Luxembourg, Slovakia, and Spain reported at least one measure each related to

85 The 24 MSs that reported a measure related to biogas include Austria, Belgium, Croatia, Cyprus, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden.

86 Further information about biomethane in the transport sector is discussed in a separate paragraph.

87 MSs that promote biomethane in at least one of their measures include Belgium, Croatia, Estonia, France, Greece, Italy, Latvia, Lithuania, Luxembourg, Portugal, Slovakia, and Spain.

the promotion of biomethane for end use consumption in the transport sector. Beyond the promotion of biomethane in the transport sector, the biomethane is also promoted in the electricity, heating, and energy sectors. The following MSs have at least one measure related to biomethane in the electricity, heating, and/or energy sectors: Belgium, Croatia, France, Italy, Lithuania, Luxembourg, Portugal, and Spain. Portugal and Spain also each reported one measure related to biomethane use in the industrial sector.

In Belgium, injection of biomethane for heat generation is supported in a planned support scheme measure, but no implementation date is provided. Biomethane production for electricity and heat generation is also supported in an obligation measure implemented in 2018 from Croatia.

Estonia reported four measures related to biomethane in the transport sector. An obligation measure implemented in 2010 specifies the share of biofuels, including biomethane, in the sector. Two measures aim to increase the supply of biomethane; one measure focuses on promoting biomethane for use in buses via grants and the other measure supports biomethane for use in heavy duty vehicles. Estonia also adopted a (strategy) measure in 2021 to support the use of biomethane in public transport.

In France, four measures are reported regarding biomethane in the transport sector. Firstly, a measure implemented in 2011 provides purchase tariffs to biomethane producers wishing to inject their production into the natural gas transport network. Bonuses are provided for purchasing heavy duty vehicles powered by biomethane fuel in a separate measure via the Finance Act, which was originally implemented in 2016, but has been extended until 2024. Two separate measures, both contained in the 2019-2028 multiannual energy program, also support biomethane. One measure plans to set up a suitable support system for biomethane for vehicles, but no further details are provided. In the other measure, which focuses on biofuel development via an incorporation incentive, a limit of 15% is set on food crops to produce biomethane. Moreover, two French measures are related to biomethane in the energy/electricity sector. One measure, implemented in 2013, consists of the Energy Methanization Nitrogen Autonomy Plan. The measure reports that as of September 30, 2022, 480 plants injecting biomethane inro the natural gas network have been set up with a total capacity of 8.5 TWh per year. Also, in 2019, another measure was implemented that allows for the right of biomethane injection when the biomethane production installation is located near a natural gas network.

A strategy measure implemented in 2016 in Greece supports innovation action in transport, including the developing of advanced liquid and gaseous biofuels through different conversion methods from sustainable biomass. No further details are provided.

Originally implemented in 2006, an obligation measure in Italy requires the release of biofuels for consumption in the transport sector and issues Certificates of Release for Consumption to entities that release sustainable biofuels; the issuance was extended to biomethane producers in 2018. Moreover, a measure from 2011 provided GOs for electricity produced from RES, which later included GOs for biomethane in addition under REDII. Also, biomethane made from waste, agricultural residues, and algae is incentivized in Italy under Ministerial Decree 2/3/2018. The incentive mechanism was accessible until the end of 2022. However, the measure was updated via Ministerial Decree 15/9/2022, which provides investment support for the construction of new biomethane production plants and the conversion of existing biogas plants. Sustainable biomethane is incentivized in a measure implemented in 2022 via support investments for biomethane fed into the natural gas network.

In Latvia, the production and use of biomethane is reported in a measure planned for 2023 with the aim of ensuring installation of production plant facilities on farms. Further details are not reported.

In Lithuania, investment support (CAPEX subsidy) for biomethane plants is also stipulated in a measure implemented in 2020. A new generation capacity of 85 ktoe of biomethane gas would be installed from 2020-2030. Another measure also provides investment support for the installation of biomethane gas production plants as part of Lithuania's waste management strategy implemented in 2021. In addition, an obligation measure is planned for 2025 requiring operators of natural gas station to supply biomethane for direct consumption.

Luxembourg reported two biomethane-related measures. One measure implemented in 2022 supports analysis and study of the technical and economic aspects of biomethane use in the transport sector. Moreover, in the Biogas Strategy measure planned for 2023, biomethane injection is incentivized, specifically for biomethane produced via valorisation of livestock effluent.

One measure in Portugal establishes incentives for production of renewable energies, including biomethane, by the agricultural and industry sectors. The measure was implemented in 2013. Adopted in 2020, a separate measure aims to study and define goals for incorporating renewable gases, especially biomethane, into the natural gas networks.

Slovakia reports one measure (classified as a regulatory/legislative change measure as an amendment to the Waste Act) that supports the collection of biodegradable municipal waste for biogas production and subsequent transformation into biomethane for use in the transport sector.

Spain reported a measure (included in the NECP #1.8, implemented in 2021) promoting renewable gases in the industrial sector, including biomethane. No further details are provided. Renewable gases, including biomethane for energy purposes in the residential sector are also supported in this same NECP measure #1.8, but information on the specific support is limited. In Spain's Biogas Roadmap measure, implemented in 2022, biomethane will contribute to reaching their target of 28% renewable energy in the transport sector. Spain also reported a measure that adopts a system for issuing GOs for renewable gases, including biomethane, as of early 2023.

Overview of measures related to sustainability criteria, ILUC-risk crops, and fraud

Sustainability criteria are explicitly reported in 10 MSs[88] in at least one of their reported measures. Of the 249 reported measures in total that are related to bioenergy (including direct and indirect measures), 211 measures across 25 MSs[89], make no mention of sustainability criteria, biomass sustainability, or the ILUC Directive in any capacity.[90] Eight MSs, including Estonia, Finland, Germany, Latvia, Poland, Portugal, Romania, and Slovakia, do not mention sustainability criteria, biomass sustainability, or the ILUC Directive in any of their reported measures. Some measures refer to GOs or other certification systems, but as they are not directly related to the sustainability criteria, they are not accounted for in these numbers above.

Regarding sustainable criteria, a biomass flow management measure reported by Belgium states that the transposition of REDII regarding the sustainability and emissions criteria for bioliquids and biofuels is under development. In Bulgaria, two separate measures implemented in 2019 include the sustainability criteria. One of these measures introduces the sustainability requirements for biofuels and bioliquids via an amendment to an Ordinance. The second of these measures introduces the methodology for calculating GHG emissions from the whole life cycle of biofuels and bioliquids from biomass, taking into account ILUC emissions in the GHG calculation and the sustainability criteria. A Croatian measure planned for 2023, the advanced biofuel market development plan, will be

88 These MSs include Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, France, Hungary, Luxembourg, and Spain.

89 These 25 MSs include Austria, Belgium, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden.

90 17 of these 25 MSs do mention sustainability criteria, biomass sustainability, and/or the ILUC Directive in other reported measures outside the 211 measures in reference. The 17 MSs include Austria, Belgium, Croatia, Cyprus, Czechia, Denmark, France, Greece, Hungary, Ireland, Italy, Lithuania, Luxembourg, the Netherlands, Slovenia, Spain, and Sweden. Details on these 17 MSs are found throughout the section.

implemented according to relevant laws based on RED, including establishing the conditions for monitoring the sustainability of biofuels and GHG savings. A measure implemented in Cyprus in 2011 to replace conventional transport fuels with biofuels requires the biofuels to meet the sustainability criteria. Originally implemented in 2004, an indirect measure reported by Czechia providing feed-in tariffs for electricity produced from RES, was amended to include biomass sustainability criteria in Act No. 165/2012. In Denmark, a biofuel share measure implemented in 2012 indicated that the biofuels must live up to EU sustainability criteria. This 2012 measure expired and was replaced by another measure in 2020, which was again replaced by another biofuel blending requirement measure in 2021, both of which also include the EU sustainability criteria. An incentive tax measure in France to promote the incorporation of biofuels in the transport sector specifies that biofuels must comply with obligations relating to sustainability criteria. Hungary reported the Green District Heating Programme implemented in 2021, stating that biomass for heating/cooling purposes is to be produced on the basis of sustainability criteria, but did not report details regarding a specific EU Directive. Luxembourg reported two measures that both include sustainability criteria. The first is an obligation measure implemented in 2022 to incorporate sustainable biofuels into road fuels, which must respect the sustainability criteria. The second measure, planned for 2023, introduces a biogas strategy and new incentives for biogas and transposes the sustainability and GHG reduction criteria provided for in REDII. In Spain, two reported measures mention the sustainability criteria: one biofuel quota obligation implemented in 2009 requires biofuels to comply with RED sustainability criteria; the other measure adopted in 2021 consists of various programs for the use of biomass for heat and electricity, of which, one program specifies promotion energy from biomass with sustainability criteria.

Since REDI and REDII include sustainability criteria, it can be assumed that when a MS implements or reports a measure in accordance with REDI or REDII that sustainability criteria are inherently included, even if sustainability criteria are not explicitly mentioned.[91] For example, Austria reports a measure that implements REDI with reference to the share of clean energy sources in the transport sector. In Belgium, a biofuel blending measure in the transport sector is reported that is in accordance with the REDII. Croatia reported a measure planned for 2023 related to transport decarbonization through the production of advanced biofuels, which is meant to implement Article 25 of REDII. A biofuel support measure from Czechia states the measure is in compliance with REDI. An indirect measure from Ireland planned for 2022 relates to renewable energy targets in the heating sector in line with REDI requirements. Luxembourg reported a measure that creates a framework for the continued deployment of renewable energies with a view to the objectives set out in REDII. In Malta, a biofuels substitution obligation is also meant to implement Article 25 of REDII. Finally, in Slovenia, a transport sector measure regarding the share of renewable energy was implemented according to REDI and the ILUC Directive.

In other MSs, biomass sustainability (as a more general concept) is mentioned in at least one of their reported measures, but not in the context of a specific EU Directive. For example, an indirect measure in Belgium extends investment support for renewable energy, including the use of sustainable and local biomass, but with no reference to a specific EU Directive. France reports two measures, both with mention of sustainable biofuels in the transport sector, one specifically related to sustainable aviation fuel. Greece reports two measures (both implemented in 2016) related to the development of liquid and gaseous biofuels from sustainable biomass. In Italy, one measure implemented in 2022 incentivizes sustainable biomethane and one other measure stipulates the issuance of Certificates of Release for Consumption to entities that release sustainable biofuels. Lithuania reported an (indirect) measure adopted in 2022 that promotes cleaner RES, such as sustainable biomass. In the Netherlands, an indirect measure to phase out coal-fired electricity plants lists sustainable biomass as an optional fuel that plant owners can use as an alternative. In

91 For older measures (implemented in 2009 or 2012) that include a reference to REDI or REDI sustainability criteria, it is uncertain whether they also include the additional and updated sustainability criteria from REDII. REDII and REDII sustainability criteria are only relevant if explicitly mentioned in the reported measure.

Sweden, two reported measures in the transport sector, one implemented in 2004 and the other in 2018, refer to the use of sustainable biofuels in the transport sector, but no further details are provided regarding any EU Directive.

Six MSs report measures related to the ILUC Directive or ILUC-risk biofuels in general. In Bulgaria, three measures are reported related to the implementation of the ILUC Directive. Firstly, a biofuel target measure in the transport sector was implemented in 2019 for the implementation of the ILUC Directive. Bulgaria reports an additional measure implemented in 2019 entitled “Amendment to the ordinance on the sustainability criteria for biofuels and bioliquids”, which sets out the rules for calculating GHG emissions from indirect land use changes. The third Bulgarian measure introduces methodology that transposes the texts of the ILUC Directive, including rules for calculating GHG emissions from indirect land use changes. In France, a measure implemented in 2019 outlines national support for biofuel development via incorporation incentives, requiring limits on biofuels made from raw materials with a high risk of inducing indirect land use change, including a ban on biofuels from palm oil (since 2020) and soy (since 2022). Luxembourg reports a measure implemented in 2022 related to the incorporation of sustainable biofuels into road fuels. The measure specifies that the limit of biofuels, bioliquids, and combustibles from biomass presenting a high risk of inducing indirect land use changes must decrease to 0% by the end of 2030. In Malta, biofuel blending obligation measure includes limits on the percentage share of biofuels produced from high ILUC-risk biofuels. One measure from Slovenia related to the transport sector was implemented according to the REDI and ILUC Directive. A Spanish obligation measure establishes limitations to UCO and ILUC raw materials in a biofuel blending measure in the transport sector.

Currently, only palm oil is classified as a **high ILUC-risk** feedstock according to the criteria included in the Delegated Regulation (EU) 2019/807, and, pursuant to Article 26 (2) of RED II. Its use needs to be phased out by 2030, **unless certified as low ILUC-risk**. As referenced in the previous paragraph, France indicates a ban on biofuels produced from palm oil in one of their reported measures, effective since January 2020. Other MSs have also excluded palm oil or have moved the phase out trajectory to an earlier date, but did not report this in the measures. For example, Austria and Germany also implemented a ban on palm oil effective July 2021 and January 2023, respectively.[92] As of January 1, 2022, Belgium also bans biofuels and biogases from palm oil.[93] See Figure 26 for more information about high ILUC and non-ILUC crops per MS.

France, Italy, Luxembourg, and Spain report using GOs. Although GOs are a useful tool to determine origin and environmental impacts, they cannot replace the verification system required by REDII for bioenergy. GOs for renewable energy production, including for injected biogas, are available in a French measure implemented in 2006. In Italy, the GOs certify production of electricity from renewable sources, including biomethane as of December 15, 2021. A reported measure from Luxembourg, which supports electricity produced from RES, also includes a system of GOs for electricity produced from biogas or solid biomass. The measure was implemented in 2014. In Spain, a reported measure, implemented in 2023, includes the adoption of a system for issuing GOs of renewable gases, including biogas and biomethane. GOs are also briefly included as part of the Spanish Biogas Roadmap measure, which was implemented in 2022, and included in another measure, which was implemented in 2021 and determines a system of GOs of renewable gases in the residential sector. There is no mention of voluntary schemes in the currently reported measures from the MSs. However, Italy reported on two measures, one related to the establishment of a National Biofuels Sustainability Certification System, and the other an update to the certification system. The Ministerial Decree 14/11/2019 established the certification system to ensure the environmental performance of biofuels at

92 USDA. (July 13, 2022). European Union: Biofuels Annual. European Union: Biofuels Annual | USDA Foreign Agricultural Service.

93 USDA. (April 9, 2021). Belgium: Belgium To Ban Palm and Soya Oil for Use in Biofuels from 2022. Belgium: Belgium To Ban Palm and Soya Oil for Use in Biofuels from 2022 | USDA Foreign Agricultural Service.

different stages of its lifecycle, including production and feedstock, as well as end use. The certification system is planned to be updated in 2023 to include provisions from the Implementing Regulation 2022 and to further define the supply chain. Additionally, Certificates for Release of Consumptions are reported in two other separate measures from Italy that incentivize the use of sustainable biofuel and biomethane. The certificates are issued to obligated suppliers that must release biofuels for consumption.

Certification systems are also included in measures reported by Poland, Portugal, and Spain. In Poland, one measure, implemented in 2006, promotes the use of biofuels in road transport and also includes a system for the certification of the quality and use of the biofuels, but no further details are provided. A renewable energy certificates of origin system, or green certificates system, is also reported in a separate (indirect) measure from Poland. The measure specifies that more than 18 TWh of electricity was generated in 2021 from renewables, including biogas, which was determined by certificates or origin and biogas certificates or origin. A quality certification system for renewable gases, including biomethane, is also introduced in a measure from Portugal. This (indirect) measure was adopted in 2020 to support the security of the energy supply and ensure that minimum quality requirements of renewable gases are met. Spain also reported on a sustainability verification system for advanced biofuels under Royal Decree 235/2018, but no details were provided in their reported measure. Another Spanish measure reported in the NECP (Measure 1.8. Promotion of renewable gases) briefly mentions the use of renewable gases supported by a certification system. The measure specifies biogas and biomethane as two possible types of renewable gases, but no further details on the certification system were provided.

Belgium also reports a biomass energy strategy measure, that includes the supervision of the use of biomass through the Biomass Transversal Committee.

21 MSs[94] submitted information regarding **observed cases of fraud**. Of these, only four MSs observed actual (or potential) cases of fraud, including Estonia, Hungary, Romania, and Sweden. Moreover, there were two cases of non-compliance in France, non-conformities found during audits reported in Italy, and some inaccuracies in procedures reported in the Netherlands. Details regarding the cases of fraud, as well as the cases of non-compliance, non-conformities, and inaccuracies are included in Section 3.3.

3.2. Overview of measures by Member State

This section provides an overview of each MSs' bioenergy-related measures, as reported in their NEPCRs. In case any additional information is provided, which is not directly sourced from the country's NECPR, this is explicitly indicated in the text, including its alternative source. It should be noted that the overview does not necessarily present every measure reported by the MS, but rather highlights the measures that are most relevant or recent. In Annex III, an overview of all the reported measures is provided in a table format for each MS.

Austria

The two relevant measures focus on increasing the share of renewable or clean energy in various sectors. In the electricity sector, quantitative targets are set in the Green Electricity Act to promote the use of biomass and biogas and are achieved using fixed feed-in tariffs. Although originally implemented in 2002, a new law to extend the scope beyond 2020 is currently under discussion. Furthermore, as part of the implementation of Directive 2009/28/EC, obligatory targets in the transport sector, such as a 14% share of fuels from

94 The 21 MSs include Austria, Bulgaria, Croatia, Cyprus, Estonia, Finland, France, Germany, Hungary, Ireland, Italy, Latvia, Lithuania, Malta, the Netherlands, Poland, Portugal, Romania, Slovenia, Spain, and Sweden.

renewables (including biofuels) by 2030, also promote the use of bioenergy. This measure was originally implemented in 2004. In this specific case, it can be assumed that biomass sustainability criteria are accounted for, since this is a continuation and update to an existing policy.

Belgium

In 2016, Belgium implemented a biomass energy strategy, which includes a Biomass Transversal Committee to supervise the use of biomass. The strategy supports reaching the target of 23.5% of final energy consumption in 2030 based on RES. No significant updates were reported.

Regulatory and legislative changes, as well as obligations are common among measure types. One measure related to biomass flow management (implemented in 2010) focuses on bioliquids and specifically corresponds to the transposition of Directive 2009/28/EC concerning sustainability criteria for bioliquids and biofuels. Sustainability criteria in accordance with REDII are also covered in a measure that promotes renewable energy in the transport sector and sets specific biofuel blending targets in diesel and petrol, including a biofuel trajectory for 2024 (10.75%)-2030 (13.9%).

Related to biofuels, one (indirect) measure under the New Marine Development Plan mentions a vision for marshland to stimulate the cultivation of seaweed as a feedstock for biofuels. The measure was implemented in 2023 as part of the decision of the Council of Ministers of 18/03/2023 to accelerate the energy transition towards greater energy independence.

Biogas production is promoted in a measure that focuses on biogas plant deployment and the production of biogas based on locally collected and recovered bio-waste and green waste. The measure is expected to start in 2024, but further details, such as measure type, are not specified. Related to this, a separate measure introduces a strategy to create a legal framework for managing and treating wastes. No details are provided regarding the strategy or the implementation dates, but legislation has apparently been adopted and is being implemented.

The injection of biomethane is also promoted by means of a support scheme based on a call system for green heat production and the use of residual heat. The measure is planned, but does not include information about the implementation timetable. However, as of January 1, 2023, customers wishing to connect to a heat network are able to apply for a connection premium in addition. An additional measure planned for 2022-2026 promotes building infrastructure for cleaner fuels, including biogas. The first charging stations are expected to be operational in the fall of 2023.

Outside of measures reported in the NECPRs, legislation will soon be finalized to accept bio-compressed natural gas (bioCNG) and bio-liquefied natural gas (bioLNG) as advanced biofuels for transport, which can be reflected in the transport obligation targets. Different incentive schemes are also available within different regions of Belgium[95], which are also not reported in the NECPRs. For example, in Flanders, an investment subsidy for biomethane production under the Heat Plan 2025 was cancelled in 2022 to prioritize heat utilization for biogas. There is also a financial subsidy entitled Ecology Premium Plus available for standardized technologies on a limitative technology list, which includes biogas produced from biomass or wastewater. Additionally, a GREEN investment subsidy is available to incentivize non-fossil energy sources for heating or cooling, including biomass that meet the sustainability criteria of REDII and biogas.[Error! Bookmark not defined.] Green gas GOs

[95] Varo, compiled by Guidehouse. (July 2023). Country profiles on biomethane.

from the local energy regulator are also available in Flanders for biomethane producers. Moreover, in Wallonia, the Walloon Commission for Energy improved a register in 2019 to include gas from renewable sources; now biomethane producers that inject biomethane into the grid are eligible to receive a guarantee of origin. Finally, an aid scheme provides subsidies for anaerobic digestion projects, which specifically allocates 1.5 million Euros for biomethane projects.

Bulgaria

All the measures reported were implemented in 2019 based on Directive 2015/1513 and REDI, therefore, the focus is on the 2020 policy framework, but not beyond. One reported measure introduces a 7% limit in the reporting of conventional biofuels, as well as a national target for new generation biofuels type "A" to meet the national mandatory target of 10% share of renewables in the transport sector. The other two measures concern safeguarding the sustainability of both biofuels and bioliquids, specifically defining the sustainability criteria and calculating GHG emissions from indirect land use changes.

Cyprus

Of the reported measures, many focus on the electricity and heating sectors. Support schemes for electricity production from renewable energy sources are reported in three separate measures. Two measures have expired, one which was operational from 2004-2013 and provided financial support for biomass heaters in residential and non-residential buildings, and the other which was operational from 2013-2018 and provided support for biomass/biogas systems in commercial and industrial establishments, as well as public buildings. The third support scheme measure (active between 2016-2018) supports the installation of commercial biomass/biogas stations that produce electricity and participate in the competitive electricity market. In 2017, 2.3MW biomass stations were licensed under the scheme. Additionally, the measure includes information that the biomass project is expected to receive their final connection terms and enter the construction phase soon, but further details are not provided.

A more recent measure under the National Municipal Waste Management Strategy aims to reduce the quantities of biodegradable waste, in part by stimulating the production of biogas for electricity and thermal energy production. The measure will be intensified from 2021-2030, but implementation of the measure has been delayed until 2024 due to delays in the adoption of the legal framework.

Since 2015, a certification program has been developed for installers of small-scale biomass boilers, which ultimately encourages biomass end use. Finally, an obligation measure implemented originally in 2011 is imposed on all transport fuel suppliers to mix biofuels (which must meet the sustainability criteria) with conventional transport fuels. The minimum share of biofuels mixed in transport fuels was increased to 7.3% in 2020.[96]

Czechia

Information beyond 2020 targets and relevant updates are not available in the reported measures. An Action Plan for biomass was implemented in 2012 until 2020 to help define appropriate measures and efficient use of biomass for energy. No further information or updates were reported.

One measure mandates minimal shares of biofuels in gasoline and diesel for the transport sector, as stipulated by Directive 2009/28/EC, which includes biomass sustainability criteria.

96 We are aware this target is for their REDI/2020 targets, but have not found any information on potential updates towards 2030 targets of this legislation.

Between 2016-2017, the high excise tax on biofuels made them more expensive than fossil fuels; however, the tax was lowered on July 1, 2017, helping to promote biofuel use. Biofuels are again promoted in a separate measure relevant in the transport sector, where biofuels are exempt from excise taxes due (planned from 2021-2030).

Biomass sustainability criteria are also introduced as part of an amendment to an indirect measure (implemented in 2004 until 2035), which incentivizes electricity produced from renewable energy sources via a feed-in tariff.

Germany

Implemented in 2000, the Renewable Energy Act supports increasing the renewable capacity in the electricity sector and energy industry through auctions and feed-in tariffs with the goal to increase installed capacity of biomass in 2030 to 8.4 GW.

A GHG quota measure was implemented in 2020. The measure includes a support program for advanced biofuels, specifically in the transport sector, but further details are not reported.

Two reported measures are related to biogas. A measure implemented in 2021 sets out the goal for the federal administration to operate in a climate-neutral manner by 2030, according to Section 15 of the Federal Climate Protection Act and the Climate Protection Program 2030. Under the Climate Protection Program 2030, several measures are approved to achieve the goal of a climate-neutral federal administration, including increasing the share of vehicles powered by biogas. Finally, increasing the efficiency of biogas plants is supported in a measure under the Federal Program for energy efficiency in agriculture and horticulture, which was implemented in 2016.

Denmark

A biofuel blending requirement was originally implemented in 2012, followed by a second measure in 2020, which increased the blending requirements from 5.75% to 7.6%. The current measure, which is in force since 2021, maintains the increased blending requirement of 7.6%. In effect, these measures promote biofuel end use. The measure from 2012 specifically indicates that biofuels must fulfil the EU sustainability criteria; since subsequent measures were an extension of this measure, it can be assumed the sustainability criteria also apply to the current blending mandate.

Biogas-focused measures across a variety of sectors, including agriculture, transport, heating, and manufacturing, are also reported. Of these measures, a few incentivize biogas use or production via a CAPEX subsidy or regulatory, or legislative reforms. One biogas measure, which will be fully implemented in 2030, utilizes a competitive bidding process, or tender, to promote biogas production under the Climate Agreement[97].

Finally, three ongoing measures should also be mentioned. Firstly, implemented in 1987, one biogas measure introduced a subsidy so that biogas sold to the natural gas grid receives the same subsidy as for biogas used at CHP plants. Also, since 1993, the Biomass Agreement measure has promoted the use of biomass in electricity production. Additionally, since 2008, renewable energy production from bioenergy has been subsidized through tender-based schemes.

Estonia

One measure implemented in 2007 provides (CAPEX) subsidies to promote electricity generation from biomass and waste. A separate measure implemented in 2014 provides

97 The measure only specifies "Climate Agreement", but based on an internet search, it can be assumed it is referring to the Danish Climate Agreement for Energy and Industry 2020.

financial support to replace local inefficient fossil fuel heating systems in households with efficient modern systems, including biomass heat pumps. In 2015, a measure to improve the performance of agricultural holdings was implemented. This measure, which is in place until 2023, provides investments (CAPEX subsidies) for the construction of new livestock facilities and for bioenergy to promote its production.

Promoting the use of biofuels, specifically biomethane, in the transport sector also stands out as a key focus among the various bioenergy-related measures. Of these measures promoting biofuels in the transport sector, various incentives are utilized. In one measure active from 2014-2020, grants were offered to promote the use of biomethane in buses. As of 2022, a total of 229 buses use biomethane. Additionally, the set goal for biomethane of 6.5 ktoe was reached and currently stands at 7.35 ktoe. To be adopted in 2036, biomethane will also be supported via a support scheme for use in heavy duty vehicles. Furthermore, a measure adopted in 2021 under the “Greener Estonia” policy goal includes a policy plan to encourage biomethane use in public transport. Additionally, an obligation measure implemented in 2010 requires an increase in the share of biofuels to at least 7.5% (as total energy) and includes a 10% target for shares of renewables in the transport sector. [98]

An indirect measure adopted in 2023 provides investments for the exploitation of bioresources, specifically to increase research and development. This measure contributes to the production of bioenergy as set out in the General Principles of Climate Policy. There is no direct mention of ensuring the sustainability criteria or GHG saving criteria in any of the measures.

Greece

Biofuels are incentivized through various measures. One blending obligation measure implemented in 2005 promotes the use of biofuels in the transport sector, particularly biodiesel and bioethanol. The mandatory blending percentages (by volume) for biodiesel and bioethanol are currently set at 7% and 5%, respectively. However, no updates for beyond 2020 have been indicated yet, except for the continuation of the current obligation. In addition, a tax incentive measure introduced in 2020 promotes alternative fuels in transport, specifically biofuels. Biofuels are further incentivized via support for development of innovative technologies in transport, explicitly, the development of advanced liquid and gaseous biofuels through different conversion processes from sustainable biomass. Lastly, one measure focuses on the instalment of systems at disposal sites for the collection and flaring of biogas in areas where the population exceeds 100,000.

Spain

One NECP measure (#1.11)[99] addresses various ways to promote electricity and heat from biomass (respecting sustainability criteria), with particular attention given to biomass of agricultural origin, obligations linked to air quality in biomass facilities, and training for installers in the biomass sector. No further details were reported. Another NECP measure (#1.5) supports biomass and other renewable thermal energy sources, such as biogas, to decarbonize the industrial sector. The measure foresees the establishment of various mechanisms including aid programs, capacity building, and sector agreements to increase incorporation of renewable energy in the sector.

Additionally, an incentive program under Royal Decree 477/2021 is available for installations of renewable thermal systems, including biomass, in the residential sector. Implemented in 2022, a separate measure calls for an auction of renewable energies to

98 Currently, there are no details or updates provided on the trajectory towards 2030 or anything beyond 2020 in the reporting framework.
99 Numbering of the measures as reported in the NECP

fulfil up to 520 MW of capacity for electricity generation. Various technologies can participate in the auction, including biomass.

Two reported measures specifically concern the introduction of biofuels, one in air and the other in maritime transport. Both measures, implemented in 2021, support advanced biofuels in either air or maritime transport, specifically production installations, adaptation of a certificate system, and establishment of consumptions objectives. Besides biofuels produced from raw materials listed in Annex IX, it is forecasted that the rest will be produced from conventional agricultural products. Another measure establishes targets for the sale and consumption of biofuels for 2021 and 2022 in road, air, and maritime transport. Also, a 2020 resolution to the National Markets and Competition Commission determines the raw materials to be used in biofuel production for transport purposes.

In addition, an obligation measure consists of a national biofuel quota system that requires fuel operators to introduce a certain percentage of biofuels in their annual sales. In 2009, the annual target was 3.4% and increased to 8.5% in 2020. The latest sustainability requirements associated with the biofuel quota are included in Royal Decree 376/2022, which implement the requirements set out in REDII[100]; however, this Decree was not reported in the NECPR.[101]

The National Air Pollution Control Program aims to reduce emissions for road, rail, aviation, and maritime transport using different technologies, including biofuels. This strategy measure was implemented in 2019. Also related to biofuels, Royal Decree 235/2018 mentions a sustainability verification system and an indicative target for advanced biofuels, but no further information is provided.

A biogas roadmap is planned for 2022-2030, which focuses on biogas production, specifically from waste and materials of agricultural origin. The roadmap includes 45 measures that support in the achievement of Spain’s biogas production target for 2030.

Also related to biogas, a measure adopted in 2021 promotes the use of biogas and biomethane in the building sector, which includes a certification system and a system of guarantees of origin and notes the potential use and exploitation of the existing natural gas network. A separate (indirect) measure, adopted in 2021, promotes the use of renewable energy, specifically biomethane in the industrial sector, but no further details are provided.

Under a Ministerial Order, another measure of relevance was implemented in 2021, which approved incentive programs for granting aid to projects of biogas facilities. First calls were made, and applications were received, but there is not further progress to report yet.

A separate measure, set to begin in early 2023, implements a system for issuing GOs for renewable gases, including biogas and biomethane. Finally, although not reported in the NECPRs, Component 7, Investment 1 of the Recovery, Transformation and Resilience Plan promotes renewable energy development, including biogas, via tenders or direct equity support.[102] 150 million Euros (out of a total investment of 3,162 million Euros) are dedicated to biogas.

Finland

To improve biomass storage capacity and energy security, one measure looks to increase the number of wood fuel terminals, but specified goals and timing of the measure are still under development.

100 REDII transposition checks are currently ongoing.
101 Varo, compiled by Guidehouse. (July 2023). Country profiles on biomethane.
102 Varo, compiled by Guidehouse. (July 2023). Country profiles on biomethane.

Obligations were, by far, the most notable measure type used to promote bioenergy. In the transport sector, there are three obligation measures related to biofuels and biogas. The first measure from 2020 temporarily lowers the minimum levels of biofuel distribution in 2022 to 12% and in 2023 to 13.5% because of high fuel prices. To compensate for this, obligation levels from 2024-2030 shall be increased up to 34% by 2030. A second measure allows for the inclusion of biogas from 2022 as part of the compliant fuels in the distribution obligation legislation. Finally, the third measure increases the obligation to biofuel distribution to 100% from 2030 by 2045.

Two measures are in place to promote the use of bioliquids: one in machinery and the other in heating of buildings. In both measures, the current legislation entails a blending obligation of 10% from 2028 onwards, but the blending of bioliquids in light fuel oil is now to be increased to 30% by 2030.

Legislation from 1997 is currently in force, which promotes biogas in electricity and heat production via investment subsidies, electricity tax subsidies, and feed-in tariffs. The latest biogas plant was approved in October 2021. Biogas for filling stations in the transport sector is also promoted by the Energy Authority, which organized six auction (tender) rounds between 2018-2022. Two other biogas promotion measures are reported, but with no detailed information on incentive mechanisms.

None of the reported measures include any further updates or additions to sustainability criteria beyond what is already in place from previous reporting obligations.

France

A variety of measure types are used to promote the use of bioenergy. Many individual measures related to bioenergy are included under the multiannual energy program (2019-2028). One measure calls for tenders for biomethane injected into the natural gas network and has set targets for biogas production for 2023 and 2028, 14 TWh (including 6 TWh injected) and between 24-32 TWh (including between 14-22 TWh), respectively. Another measure promotes the development of a support system for biomethane not injected into the natural gas network, for example, biomethane used for bioNGV vehicles. Moreover, there is a measure to support the development of biofuels using an incorporation incentive. In addition to the ceiling on conventional biofuels, this measure also sets a limit on biofuels from raw materials that present a high risk for inducing indirect land use changes and bans biofuels produced from palm oil. Another measure under the multiannual energy program was implemented in 2019, also under the multiannual energy program, which consists of a clean mobility strategy and includes increased development of biofuels.

Other strategies are also employed, such as the National Biomass Mobilization Strategy and the Energy Methanization Nitrogen Autonomy Plan. The National Biomass Mobilization Strategy, implemented in 2018, defines guidelines and recommendations for developing biomass production and increasing its mobilization, especially in recovery sectors. Additionally, the Energy Methanization Nitrogen Autonomy Plan has promoted the installation of biogas facilities and biomethane plants for injection into the natural gas grid since 2019 and is still ongoing.

Financial incentives are available as part of the Finance Act (originally introduced in 2016) for vehicles purchased that are powered by natural gas and biomethane fuel. The scheme was strengthened and extended three times: until 2021, extended again until 2024, and finally extended until the end of 2030. A financial incentive is available in a separate measure for heat production projects based on renewable energies, including biomass. The measure guarantees a price for heat from RES at 5% lower compared to conventional energies. The measure was implemented in 2019 and is relevant for the agricultural, building, heating, and industry sectors.

A tax incentive is available since 2005 to promote the incorporation of biofuels in the transport sector. Operators are penalized if they use a proportion of biofuels lower than defined thresholds; the threshold in 2023 is 8.5% for diesel and 9.5% for petrol. These biofuels must comply with obligations relating to sustainability criteria.

An obligation measure requires the incorporation of biofuels into aeronautical fuels. From 2022, the incorporation rate of biofuels at 1% is mandatory.

Biomethane injected into the gas network is promoted in two different measures. One measure, implemented in 2011, offers purchase tariffs for biomethane injected into gas network. A natural gas supplier can purchase biomethane at a fixed price, which makes it possible for the biomethane producer to cover investment and operating costs and ensure profitability of the project. This measure support achievement of the national objective of 10% of gas produced from RES in 2030. The second biomethane-related measure was implemented in 2019 and allows for the right of injection of biomethane for production plants located near a natural gas network. Details on this measure presented in the NECPR are limited.

Another measure provides guarantees of origin since 2006 for renewable energy production, including for injected biogas. These GOs support biogas production, as they can be valued on the market and constitute an additional source of income for producers.

Many measures outside those reported in the NECPRs are important to mention[103]. Firstly, feed-in tariffs are available for biogas for electricity generation, which includes a premium for using manure. This tariff is due to be revised in 2023 to biogas plants less than 400 kWe, but a new feed-in premium will be added in 2023 for biogas plants between 400 and 1,000 kWe. There is also a feed-in tariff for injected biomethane, which was first introduced in 2011, but revised in 2020 and 2021, with the aim of supporting the 2023-2028 target for an injection of 7-10% renewable gas. Additionally, a new biomethane tendering scheme is set to be launched, originally in December 2022 followed by two rounds in June and December 2023, but no rounds have been opened as of June 2023. Furthermore, a biogas production certificate scheme expected to be launched in 2023 requires gas suppliers to obtain biogas production certificates either by buying them from biomethane producers or producing the volume of biomethane themselves. There is also a guarantee of origin scheme for injected biomethane, which includes REDII requirements on feedstock sustainability and GHG emission savings for biomethane facilities over a capacity of 19.5 GWh.

Croatia

Biofuels and biogas are strongly promoted using different mechanisms. For example, one measure implemented in 2018 promotes renewable energy sources for electricity and heating generation, mandating the use of biowaste in biogas plants for biogas and biomethane production. Another measure, also implemented in 2018, stimulates biogas production using litter and manure. Biogas and biofuel are support in a separate measure for the development of an industrial complex, which is planned for 2023-2026, and includes a plant for the production of advanced bioethanol, as well as a plant for the production of biogas. Regarding advanced bioethanol, the measure states that production is in accordance with Part A of Annex IX of Directive (EU) 2018/2001.

Biofuel sustainability and greenhouse gas savings are again considered in a regulatory measure planned for 2023 to develop an advanced biofuel market. This measure not only

[103] Varo, compiled by Guidehouse. (July 2023). Country profiles on biomethane.

helps achieve the planned share of advanced fuels in direct energy consumption in the transport sector, but also supports the broader goal to increase the share of renewable energy sources in the transport sector by 2030. Finally, it is planned in another measure that starting in 2023, fast-growing crops (planted and sown exclusively for the production of biomass for energy production), remnants of the winter harvest, and post-harvest residues should be collected and processed for energy purposes.

Some indirect measures are also reported, five of which are related to renewable energy sources in the transport, electricity, of heating sectors and one measure related to the development of the bioeconomy.

Hungary

Since 2021 under the Green District Heating Programme, biomass production is promoted for heating and cooling purposes. According to the measure, this biomass must meet the sustainability criteria.[104] The measure further encourages the use of biogas of agricultural origin, although the specific incentives used have yet to be developed. Also implemented in 2021, a mandatory blend rate of biofuels in the transport sector was set to 8.2% due to a change in legislation. Moreover, another reported measure adopted in 2016 under the National Policy Framework has set national targets for 2020, 2025, and 2030 for the deployment of alternative fuels infrastructure, specifically biofuels. Legal and financial incentives for the use and research and development of the fuels are available Biogas is also supported in a measure implemented in 2009 via Government Decree 19/2009, which allows biogas producers to participate in the natural gas market as a way to decrease import dependency. No details are provided.

Ireland

The Support Scheme for Renewable Heat and the Renewable Heat Programme both provide financial incentives to encourage uptake of renewable energy for heating purposes, with specific inclusion of biomass boilers and biogas heating systems. The Renewable Heat Programme further stipulates technical assistance, monitoring, and knowledge-sharing opportunities regarding renewable heat technologies. These measures are ongoing.

Regarding biofuels in the transport sector, the Renewable Fuels for Transport Policy Statement 2021-2023 indicates a trajectory of annual increase in the obligation rate for renewable transport fuels, specifically bioethanol and biodiesel, to meet 2030 targets set out in the Climate Action Plan 2021.[105] The obligation rate specifies a blend of E10, which refers to a rate of up to 10% by volume of bioethanol blended into petrol, and B20, which refers to a rate of up to 20% biodiesel blended into diesel.

One indirect measure obliges Ireland to achieve a 12% share of renewable energy in the heating sector by 2020[106] in line with requirements of Directive 2009/28, which includes biomass sustainability criteria. Besides this, there is no explicit mention of biomass sustainability criteria in any other measures.

Italy

An obligation measure for the mandatory release of biofuels for consumption was originally implemented in 2006. Updates have been made over the years to include mention of sustainable biofuels. For example, Certificates of Release for Consumption are issued to

104 The reported measure only states "biomass produced on the bases of sustainability criteria for heating/cooling purposes." REDII is not explicitly mentioned.
105 In early/mid-2023, the Renewable Transport Fuel Policy 2023-2025 was announced, which indicates updated rates for renewable transport fuels and underpins the biofuel targets of at least B20 (biodiesel equivalent) in diesel and E10 (ethanol) in petrol by 2030 with interim targets for 2025. However, this policy was not reported in the measures.
106 The reported measure indicates a start year of 2022.

entities that release sustainable biofuels. In 2018, these certificates were also made available for biomethane producers. Additionally, in 2020, sustainable biofuel inputs were required to make up at least 8.1% of the energy content of gasoline and diesel fuel, on top of the 0.9% obligation under a 2018 Ministerial Decree, for a total obligation of 9%. A subsequent 2021 measure under Legislative Decree (199/2021) allowed for updates to the conditions, criteria, methods, and targets for implementation, including feed-in obligations from 2023-2030. Although not directly stated in the reported measure within the NECPR, Decree 199/2021 also allegedly transposed the REDII, which was followed by a subsequent 2023 Decree that set out the latest blending obligations and penalties.[107,108] Outside reported measures in the NECPRs, it is also important to mention a 2023 Decree that has established the latest blending obligations and penalties, including a dedicated quota of 5.7% for biomethane in 2030.[109]

Certificates are a commonly used method for supporting biofuels and biogas. A measure implemented in 2020 introduced a National Biofuels Sustainability Certification System to ensure environmental performance of biofuels at life cycle stages. A new measure planned for 2023 provided updates to the certification system to further characterize the supply chain.

A 2016 Decree updated a former 2012 Decree, which incentivized electricity production from non-photovoltaic renewable sources via participation in actions or financial incentives in the form of registers. In 2018, Law No. 145 allowed for the inclusion of biogas plants built by farmers with specific biomass feedstock requirements into the incentive scheme. Financial incentives are also available in a measure planned for 2023 that supports electricity production from innovative RES. The measure establishes methods and conditions under which plants powered by biogas and biomass can access the incentive.

Another measure incentives biomethane and advanced biofuels made from waste, agricultural residues, and algae via Certificates of Release for Consumption with a duration of 20 years under Decree 2/3/2018. The incentive was only assessable until the end of 2022. However, this measure was updated as part of a new measure under Decree 15/9/2022, which incentivizes new sustainable biomethane production plants and the conversion of existing biogas plants. The Decree specifically promotes biomethane injected into the natural gas network via capital support and provides incentive tariffs for net biomethane production. A call for proposals was made in early 2023. Biomethane is also supported in an (indirect) measure for electricity purposes via GOs; the measure was originally implemented in 2011 for renewable energy sources but was extended to include biomethane on December 15, 2021. Adopted in 2021, a separate (indirect) measure provides an update to GOs, including updates on the methods for issuing, recognizing, and cancelling GOs.

Lithuania

Promotion of small-scale biomass cogeneration is reported in a measure implemented in 2019. A total of four project agreements are signed with results planned for 2024-2025.

Promotion and production of biofuels in the transport sector is noteworthy. Firstly, a blending obligation implemented originally in 2011 is updated to reflect a target of 10% (previously 5%) of bioethanol per litre of fuel starting January 1, 2020 and maintain the 7% of biodiesel per litre of fuel. Another obligation measure planned to start in 2025 requires operators of

[107] Varo, compiled by Guidehouse. (July 2023). Country profiles on biomethane.
108 The REDII transposition checks are currently ongoing.
[109] Varo, compiled by Guidehouse. (July 2023). Country profiles on biomethane.

natural gas stations to supply a fixed amount of gas from renewable energy sources, with biomethane of particular interest.

One measure, implemented in 2018, promotes biofuels for heat generation in district heating systems. Details on the measure are limited and there is no progress to report for 2020 or 2021. Another measure, also with a focus on the heating sector, plans to increase biofuel capacity with biomass boilers up to 2030. The measure was implemented in 2021 and first results are planned for 2026.

The installation of local and renewable energy cogeneration plant projects are planned in a separate measure with specific plans for a biofuel unit to start operation in the 2023-2024 heating season, which is already a delay due to construction setbacks. Moreover, under the Climate Change Programme, investment support is available until 2023 in the form of subsidies and grants for the installation of new or adaptation of existing biomethane gas production and/or biogas purification plants, which specifically treat biological (food and kitchen) waste. Support for second generation bioethanol is available in a measure adopted in 2022, allowing for an additional 12.4 ktoe of second-generation biofuels on the market. Since the measure only started in 2022, there is not yet any progress to report.

Investment support is available for livestock farms that produce biogas from manure. The measure was originally adopted in 2019 but was updated in 2023 to account for a changing fee, but no further details are provided.

Biomethane, specifically the production of, is further stimulated with CAPEX subsidies in another measure. These subsidies support the installation of biomethane plants to increase generation capacity between the period 2020-2030. The first projects are currently underway.

The only attention given to biomass sustainability in the reported measures is in two (indirect) measures, both related to renewable energy deployment in industry, where sustainable biomass is listed as an example of a renewable energy source.

Luxembourg

Solid biomass is supported in four reported measures. The first of such measures was implemented in 2015 and promotes the recovery of wood-rich green waste as a heat source in biomass power plants. A separate measure, implemented in 2021, provides an aid scheme for municipalities for energy efficiency and renewable energy projects, including biomass cogeneration plants. The scheme is set to be revised and strengthened for the year 2023/2024. Also, a measure is planned related to arable land management that specifies the production of biomass for energy production. Few details are provided, and the start year is yet to be confirmed. Finally, a fourth measure, implemented in 2014 provides a framework for deployment of renewable energies with a view to the objectives set out in REDII. This measure includes guaranteed remuneration in the form of injection tariffs or market premiums for electricity produced from biogas, solid biomass, and waste wood.

A measure implemented in 2022 entitled ‘Obligation to incorporate sustainable biofuels into road fuels’, sets an 8% target rate of biofuels for 2022 and 2023 and includes targets for 2025 (8.8%), 2030 (10%), 2035 (14.4%), and 2040 (18.7%). The measure specifies that biofuels must meet the sustainability criteria. Moreover, the measure stipulates a 5% limit on the share of biofuels from cereals and other starchy crops grown as main crops primarily for energy production, a 5% limit on the use of first-generation biofuels, as well as a limit for biofuels, bioliquids, and combustibles from biomass presenting a high ILUC-risk (0% at the end of 2030). The contribution of advanced biofuels and biogas produced from Annex IX, Part A feedstocks is also set at 0.2% in 2022, 1% in 2025, and at least 3.5% in 2030.

Three reported measures deal with biogas injected into the natural gas network. Implemented in 2011, one measure prioritizes the collection of biowaste for the purpose of increasing biogas production. As a result of the measure, a total of 24 biogas installations were in place in 2022 and connected to the natural gas distribution network. A separate measure provides remuneration for biogas injected into the natural gas network and encourages the valorisation of livestock effluent in new and existing power plants. The measure reports it has been implemented but does not provide information about the timeframe. Also, a measure planned for 2023, outlines a national biogas strategy, including financial incentives for biogas, with the goal of increasing the gross production of biogas to 330 GWh per year.

One measure specifies the need for analysis and study of technical and economic aspects of biomethane use in the transport sector, as well as the need for financing. The measure was implemented in 2022.

Latvia

Two active measures are important to note, both of which provide investment support (CAPEX subsidies) or grants for renewable energy sources-heat technologies, including biomass. In addition, in 2009, a biofuel blend obligation was announced for bioethanol and biodiesel; mandatory volumes of blend were increased in 2020 from 4.5-5% to at least 9.5% for bioethanol and from 4.5% to 6.5% for biodiesel. Additionally, the use of biomethane and the production of biogas and biomethane are promoted, which includes a target amount of manure to be used for biogas production in 2030. However, no incentivization method is specified. Neither biomass sustainability criteria, nor GHG saving criteria are explicitly mentioned in any of the reported measures.

Malta

The singular reported (related to bio) measure implemented in 2021 promotes the end use of biofuels based on a biofuels substitution obligation which is now extended until 2030 and increased to at least 14% share of renewable energy sources for final consumption in the transport sector, of which 3.5% is advanced biofuels. The measure also set limits on the share of biofuels produced from food and feed crops and high ILUC-risk biofuels. Furthermore, the measure states that in a Legal Notice (336) of 2021 the imposed minimum biofuel content on biofuel suppliers is to be in line with requirements of the REDII recast.

The Netherlands

Reported measures are either indirectly linked to bioenergy, are expired, or have been updated to exclude biomass. One expired subsidy scheme (2020-2021) with a focus on liquefied natural gas (LNG) also supported solutions for bioLNG. Another subsidy scheme supported projects for sustainable transport solutions between 2017-2021, including biofuels for air, water, and heavy road transport. Yet another investment subsidy scheme, which started in 2016 with the goal of contributing to reducing gas consumption in heating, provided allowances for the purchase of various small renewable energy systems, including biomass boilers. However, since 2020, the scheme was limited to heat pumps and solar water heaters. Finally, sustainable biomass is mentioned briefly in an indirect measure related to phasing out coal-fired electricity plants by 2030.

The VertiCer certification system, mandated by the Minister of Economic Affairs and Climate, is also relevant, but it is not reported in the NECPR.[110] VertiCer is a certification body responsible for issuing guarantees and certificates of origin for electricity, renewable thermal energy, hydrogen, and biomethane. VertiCer is the successor of two former certification bodies, Vertogas and CertiQ, as of January 1, 2023.

Poland

Biofuels are promoted in the transport sector in a measure that provides a scheme of incentives and support instruments. The measure was implemented in 2006 and supports reaching the 14% share of renewable energy in the transport sector in 2030.

Biomass and biogas installations (with a total installed electrical capacity of no more than 1 MW) are incentivized via a system of feed-in tariffs and renewable energy subsidies in a measure implemented in 2016. A separate measure, adopted in 2023, provides investment support to farms that construct agricultural biogas plants up to 50kW. Co-financing is also available for improving energy efficiency of farm buildings, which includes the reconstruction or purchase of biomass boilers.

Another biogas-related measure, implemented in 2010, supports the development of agricultural biogas plants for the purposes of electricity and heat generation. The specific mechanisms of support are not specified.

One (indirect) measure consists of a renewable energy certificates of origin system, or green certificates system. Based on certificates of origin and biogas certificates of origin, more than 18 TWh of electricity was generated in RES installations in 2021. No measures address the biomass sustainability criteria as per REDII.

Portugal

Biomass-based electricity generation and biomass collection and storage are supported alongside the development and improvement of forest management in a measure implemented in 2019.

Biofuels and biogas are also commonly highlighted among the reported measures. Regarding biofuels, two measures implemented in the late 2010s are indicated. As part of the National Acton Framework for an Infrastructure of Alternative Fuels, a measure implemented in 2017 supports biofuel production and consumption. Financial support for related development projects was made available through the Portuguese Innovation Support Fund for projects with execution deadlines between 2020-2023. Another measure implemented in 2020 encourages research, development, and innovation in various fields, including biofuels, to support the transition to a carbon neutral economy.

One biogas regulation adopted in 2020 under Decree-Law No. 231/2012 contributes to greater injection of renewable gases, particularly biogas and biomethane, into the natural gas transmission and distribution networks. Although the regulation started in 2020, the definition of technical requirements for the renewable gases are still in execution, according to the reported measure. A separate measure implemented in 2013 also established incentives for biomethane production by the agricultural and industry sectors. An additional measure implemented in 2020 promotes the use of renewable energy in heating and cooling systems until 2030, including boilers adapted to renewable gases and biomass boilers.

There are also a variety of measures indirectly related to bioenergy, which focus more broadly on renewable energy sources, but with no specific incentive for or mention of

[110] Varo, compiled by Guidehouse. (July 2023). Country profiles on biomethane.

bioenergy. One indirect measure adopted in 2020 evaluates and set targets for incorporating renewable gases, including biomethane, into the natural gas network, for example. Portugal also reported a measure with the goal of defining and implementing a certification system for renewable gases (with mention of biomethane) to ensure renewable gases comply with the minimum quality requirements and do not jeopardize energy supply. The measure was adopted in 2020. No measures address the updated or new biomass sustainability criteria as per REDII.

Romania

Implemented in 2018, fuel suppliers are obliged to market diesel with a biofuel content of at least 6.5% of total volume. The use of CAPEX subsidies and support schemes are also common among the reported measures. For example, one measure provides investment support since 2022 to produce electricity from renewable sources on agricultural land, which includes a production capacity of energy from biomass, bioliquids, and biogas to a maximum area of 50 ha. In addition, a state aid scheme, also implemented in 2022, supports investments for energy production from less exploited renewable sources, in particular, biomass and biogas.

Two (indirect) strategic measures were also reported. The first measure establishes a promotion system for energy production from renewable energy sources, with mention of biomass as an example. The measure does not specify what the promotion system entails but explains that the original law from 2008 was amended in 2010 and 2022 to reflect national contributions for 2030. Finally, feedstock availability is stimulated indirectly through a 2022 measure for the approval of the National Strategy of Forests, which focuses on implementing tools and establishing more accurate data related to efficient resource use (wood) under Governance Regulation Article 20(b)(8).

Biomass sustainability criteria are not explicitly mentioned.

Sweden

One method in which biofuels are promoted is through carbon dioxide taxes. In two different measures, one implemented in 1991 and the other in 2004, biofuels are exempt from carbon taxation, which incentivizes biofuel use by default. The more recent measure also makes note of sustainable biofuels, as they are exempt from both the carbon and energy tax from July 2018. However, the carbon dioxide and energy tax exemption schemes were revoked in December 2022 by the EU General Court for all biogas used for transport and/or heating purposes; this leaves the future of Sweden's biogas and biomethane industry uncertain.[111] This revocation was not reported in the NECPR.

Sustainable biofuels are promoted in a fuel blending obligation measure in the transport sector. Since the measure was implemented in 2018, the level of biofuels consumed has increased.

In accordance with Directive 2008/98/EC, the "Waste Framework Directive", the collection and treatment of biowaste is required by the end of 2023. Therefore, Sweden has planned biowaste-relevant legislation requiring municipalities to collect food and kitchen waste to be used to produce biogas starting January 1, 2024.

Manure-based biogas production is also supported via CAPEX subsidies and/or support schemes in two different measures. One subsidy runs from 2014-2023. The other subsidy began in 2015 as a support scheme for biogas production for generation of electricity, heat, or to be used as vehicle fuel. Between October 1, 2019 and September 30, 2020, 65 biogas

[111] Varo, compiled by Guidehouse. (July 2023). Country profiles on biomethane.

plants received a share of 29.9 million Swedish Krona (SEK) and generated 178 GWh. New support was added in 2022 for biogas producers for upgraded biogas either to be used in the natural gas network or as vehicle gas.

Outside what was reported in the NECPRs, a few measures are important to present[112]. To begin, the Sustainability Act (2010/598) regulates the national REDII sustainability criteria scheme. Within the scheme, sustainability decisions can be granted by the Swedish Energy Agency. These decisions also are used to demonstrate compliance with the REDII sustainability requirements for biomass fuels as of January 2022. Finally, the “green gas” concept, introduced in 2011, is also of interest The concept is a mass balancing approach that offers virtual purchasing of biogas between a consumer and supplier and ultimately helps to address the issue of the highly fragmented gas grid in Sweden.

Other indirect measures are available, but not elaborated on here.

Slovenia

CAPEX subsidies are commonly used in the reported measures. Two measures incentivize the production of fuels, specifically biogas with manure (wastes). Of these measures, one was implemented in 2004 under the Rural Development Programme. The other was implemented in 2023 to directly incentivize the construction of small and micro biogas production plants. A further measure implemented in 2022offers subsidies and soft loans for the construction of small installations of renewable energy sources, specifically biomass for electricity generation.

Support schemes are used in three separate measures, all in the electricity and heating sectors. The most recent support scheme, implemented in 2021, promotes electricity generation from renewable energy sources and CHP. However, it was upgraded in 2022 and again in 2023, to allow for the entry of CHP plants using wood biomass. Another measure planned for 2023 specifies available investments for wood biomass co-firing, with the overarching goal of supporting technological modernization of thermal electricity plants. Finally, one measure offers a feed-in tariff scheme to promote electricity production from renewable sources (including solid biomass and biogases) and in CHP (including gas and solid biomass fired). The scheme was implemented originally in 2001, modified in 2009 and 2014, and the most recent version was implemented in 2022.

Slovenia implemented a Law on renewable energy sources and a Decree on renewable energy sources in transport, in line with EU Directives 2009/28 and 2015/1315, which therefore includes the REDI sustainability criteria. In addition, according to the NECP, the share of renewable energy shall amount to 21% in 2030, and specifically 11% for biofuels in 2030.

Additional measures are planned for 2023 to increase the share of renewable energy sources in transport fuels, especially advanced biofuels, but no specific details are reported.

Slovakia

Implemented in 2013, the ‘Implementation of the EU Emissions Trading System’ measure stimulates the use of biomass in the fuel mix of energy producers. Additionally, a separate measure, implemented in 2015, engages private households in alternative energy generation, including heat generation for residential buildings, such as biomass via a support scheme. Also, the ‘Implementation of the Fit for 55 package’ measure, planned for

[112] Varo, compiled by Guidehouse. (July 2023). Country profiles on biomethane.

2022, includes support for increasing the consumption of biomass for electricity and heat production.

Biofuels are supported in three separate obligation measures in the transport sector. One measure stipulates the mandatory blending of bio-components into motor fuels at a share of 14% between 2006 and 2030. A measure implemented in 2010 requires an increase in the share of renewable energy in road transport fuel consumption, which includes biofuel blending obligations every year from 2020 (7.6%) until 2030 (11.4%). In another measure, the blending of advanced biofuels into motor fuels is compulsory to contribute to an overall target of 14%. The measure was implemented in 2019.

One biogas-related measure involves processing animal waste for biogas production to support biogas use as a local energy source. The measure is planned for 2025 and currently only outlines options for support, but must still be adjusted for legislative approval. Additionally, another measure focuses on collecting biodegradable municipal waste with a secondary focus as part of the long-term strategy on the production of biogas and biomethane, which can then be used either in the transport sector or injected into the grid. This measure has been implemented as of 2023.

Two indirect measures are worth noting. One measure, implemented in 2021, aims to support improving the thermal performance of buildings. This measure contributes to achievement of the long-term strategy, specifically supporting renewables in electricity production, such as biogas/biomethane and biomass. Another measure, implemented in 2022, provides subsidies to improve energy efficiency by modernizing energy systems, including increasing the number of district heating systems. This measure supports the achievement of the long-term strategy, including the transition from fossil fuels to biomass in district heating systems.

3.3. Reported and observed cases of fraud

Reported and observed cases of fraud

21 MSs submitted information regarding observed cases of fraud. These MSs are Austria, Bulgaria, Croatia, Cyprus, Estonia, Finland, France, Germany, Hungary, Ireland, Italy, Latvia, Lithuania, Malta, the Netherlands, Poland, Portugal, Romania, Slovenia, Spain, and Sweden. Six MSs did not report any information regarding fraud including Belgium, Czechia, Denmark, Greece, Luxembourg, and Slovakia. Of the 21 MSs that submitted information, only four reported actual (or suspected) case of fraud. In Estonia, one case of potential fraud related to false reporting on the use of advanced biofuels was reported; this case is currently in proceeding. Additionally, false content was identified in various sustainability certificates in Hungary. Violations of the Hungarian Government Decree 279/2017 (IX. 22)[113] were identified (12 in 2020 and one in 2021) and the involved companies were thus removed from the Biofuel Greenhouse Gas Emission register. Also, Romania has obtained letters of formal notice from the EC in 2020 insisting that they properly implement the EU Timber Regulation, which prevents timber companies from producing and selling products made of illegally harvested logs on the EU market. Since then, Romania has made progress and also updated their timber tracking system. Finally, Sweden also reported fraudulence in the waste sector.

Reported cases of non-compliance, non-conformity, and inaccuracies detected during the audits

Three MSs reported cases of non-compliance, non-conformity, or inaccuracies. In France, two non-compliance cases were observed during audits regarding sustainability certificates in trading operations. However, after an investigation, it was concluded that these cases were unintentional and since then, the two operators have applied the correct sustainability certificates to the transactions concerned. Moreover, non-conformities were found during audits in Italy, but these have been properly addressed. No further details were reported. Lastly, although no fraud cases were observed in 2020 and 2021 in the Netherlands, some inaccuracies in procedures were reported following audits of bunker companies. Inaccuracies generally stemmed from the use of a non-fixed default value in reported energy biofuel values. Enforcement action has been taken by the Dutch Emissions Authority to correct and prevent further inaccuracies.

113 GD 279/2017 (IX.22.) Government decree on the sustainability requirements and certification of biofuels and liquid bio-energy carriers, which defines the requirements for the sustainable production, the certification, the compulsory biofuel share.

4. Sustainability of bioenergy consumed in the EU

Biofuels, bioliquids, and biomass fuels should always be produced in a sustainable manner. Biofuels, bioliquids, and biomass fuels are required to fulfil sustainability and GHG emissions saving criteria to count towards the Union overall and sectoral targets, as specified in the REDII, and to benefit from MS support schemes. Besides the impacts as safeguarded by these criteria, there are a range of broader (direct and indirect) potential effects that the EC wants to monitor, so as to timely identify any other concerns related to increased biomass consumption in the EU. Therefore, the objective of this task is to provide an updated state of play (data and analysis) on a broad range of elements related to the sustainability of bioenergy and biomass consumed.

4.1. Environmental costs and benefits, security of supply and balanced approach between domestic production and imports

By bringing together the quantitative and qualitative data that is presented in the other sections of this report, the key impacts of bioenergy in the EU can be highlighted. This section describes a view on import dependency of several feedstocks, reflects on the environmental impacts of several feedstocks, and assesses the impact of recent EU policies. It is structured along the categories of solid biomass, biogas, and liquid biofuels.

Solid biomass

Within the NECPRs, solid biomass is reported in the following three categories: forest biomass, organic waste biomass, and agricultural solid biomass. According to the NECPRs, 19% of the forest biomass used for energy purposes is imported into the EU in 2021. When looking at the different feedstocks, 8% of the woodchips are imported, 34% of the wood pellets, and 6% of roundwood. The NECPRs do not disclose the geographic origin of the import, but the geographic origin can be traced back using the Eurostat trade balances for wood pellets and wood chips.[114] **Error! Reference source not found.** Table 14 below provides an overview of the share of the geographic origin of wood pellets and wood chips used for biomass in EU for energy purposes, based on the total amounts reported by MSs in the biomass questionnaire and the share of the total import based on geographic origin from the Eurostat trade balances. Even though the EU has an Import dependency of 35% of Russian wood pellets, when looking at the total forest biomass used for energy purposes in 2021, this ends up being 0.7%. The import dependency for wood pellets from the USA is also 0.7%. The total import dependency on wood pellets and wood chips is therefore low when looking at the total forest biomass used in the EU for energy purposes. The environmental impacts for these categories are minimal, since typically these are produced from forest and sawmill residues. These could theoretically be produced from primary biomass, but that is oftentimes not the most economically optimal feedstock. Roundwood is included in the category ‘primary forest biomass’, and its use for energy purposes could have larger environmental impacts. If a forest is selectively harvested for the purpose of bioenergy production, it is crucial to consider the potential significant consequences that may arise. The implementation of the forest harvesting sustainability criteria should minimize these direct potential environmental risks during harvesting. All harvesting is safeguarded by Union policies such as LULUCF and sustainability criteria for forest biomass used for the production of energy within REDII and Commission Implementing Regulation

114 Trade balances data report for all feedstock purposes, thus not exclusive for energy purposes like the biomass questionnaire. Source: Eurostat EU trade since 1988 by HS2-4-6 an CN8

2022/2448, thus the direct environmental impacts related to the category of roundwood are expected to be minimal.[115]

Table 14: Geographic origin of wood pellets and wood chips, as a share of the total forest for EU biomass consumption of energy in 2021

	Wood pellets	Wood chips
EU	3.8%	11.3%
Russia	0.7%	0.4%
United States	0.7%	
Belarus	0.2%	0.4%
Ukraine	0.2%	
Canada	0.1%	

Regarding organic waste biomass, only four MSs[116] reported imports of organic waste biomass in the solid biomass questionnaire as part of the NECPRs. Sweden imported 27% of their total organic waste biomass for energy purpose usage, followed by the Netherlands (14%) and Belgium (10%). The most popular category to import was renewable fraction of industrial waste, of which Sweden imported 7,176 thousand m^3 (18% of the total organic waste biomass used in Sweden in 2021). Sweden could therefore be at risk of import dependency of renewable fraction of industrial waste. The MSs did not have an obligation to report from which country they import the organic waste biomass. Ultimately, it is not possible to judge the import dependency of the EU, as only four countries submitted import data.

MSs did not report any import of agricultural solid biomass for heat or electricity (energy crops or crop residues) in the NECPRs. Additionally, MSs did not report which energy crops or the type of residues were included in the indigenous production for heat or electricity. The section below on 'Bioliquids' will provide an overview of the environmental risks per feedstock for bioliquids, which include energy crops. The environmental risk for agricultural residues is minimal for domestic production due to the requirements set in the REDII Article 29(2) to safeguard soil quality and soil carbon when harvesting agricultural residues.

Biogas

Since no data is reported in the NECPRs or Eurostat considering biogas feedstock and its trade, it is not possible to distinguish import dependencies. When the Union database would come online, more such data could become available. Due to this data gap, it is not possible to provide insights into which main feedstocks are used to produce biogas. In the case that this would be similar crop-based feedstocks as used for biofuel production, also similar land use and environmental impacts would be applicable. However, if biogas would mainly be produced from manure, waste, or cover crops, this would lead to much fewer land use and environmental impacts.

The RePowerEU package strongly advocates for the significant role of biomethane sustainably produced from organic waste, forest, and agricultural residues in the EU gas market. In 2021, no significant growth of EU biomethane demand can be observed (yet). It is possibly too early to already see the impact of this policy package in statistics, as RePowerEU was only published in 2022.

115 Please note, this brief analysis does not reflect on where roundwood should be used (for example according to the cascading principle), but only on the potential risks of direct environmental impacts.
116 Belgium, The Netherlands, Portugal, and Sweden. Portugal reported using zero organic waste biomass and will therefore be excluded from further analysis.

Liquid biofuels

In the current situation, EU feedstock accounts for just less than 59% of EU biofuels. Imported feedstocks account for 45% of the feedstock used for biodiesel and 8% of the feedstock used for bioethanol. For biodiesel, rapeseed mostly originated from within the EU (77%), whereas palm oil- and soy-based biodiesel are mostly imported (100% for palm oil, 87% for soy), see Table 2 in section 2.2.1. The EU imports palm oil for biodiesel mainly from Indonesia and Malaysia, of which, 65% of the palm oil is estimated to originate from Indonesia and 29% from Malaysia. The three largest soy exporting countries to the EU for biodiesel are Brazil (40%), the USA (21%), and Argentina (18%). Table 15 below provides an overview of the estimated geographic origin of the biodiesel and bioethanol feedstocks used to meet the 2021 EU demand for biofuels. The highest non-EU country of origin for biofuel feedstock is Indonesia. Nearly 11% of the EU biofuels were dependent on Indonesian feedstock in 2021. Indonesia is followed by Malaysia, which has almost a 4.5% share of the total biofuel feedstock market. These two countries are the major palm oil exporting countries. Sugar cane-based bioethanol is 100% imported, mainly from Brazil, which represents 0.2% of the total biofuel consumption in 2021.

Table 15: Geographic origin of the imported biofuel feedstocks, as a share of the total biofuel feedstock used for biodiesel and bioethanol[117]

	Biodiesel					*Bioethanol*							
	Rapeseed	**Palm oil**	**Soybean**	**UCO**	**Animal fat**	**Wheat**	**Corn**	**Barley**	**Rye**	**Sugar beet**	**Sugar cane**	**Cellulosic**	**Total**
EU	25.8%		0.8%	8.2%	6.5%	3.6%	6.2%	0.6%	0.6%	6.3%		0.2%	58.8%
Argentina			1.3%	0.1%									1.4%
Australia	2.9%			0.0%									2.9%
Brazil		0.0%	2.6%				0.3%				0.2%		3.1%
Canada	1.8%		0.4%				0.1%						2.2%
China				3.9%									3.9%
Indonesia		9.7%		1.1%									10.8%
Malaysia		4.3%		1.3%									5.7%
Ukraine	2.7%		0.1%	0.0%			0.6%						3.5%
USA			1.3%	0.2%			0.5%						2.1%
Russia						0.0%	0.0%						0.1%
Other	0.4%	1.0%	0.1%	3.5%		0.0%	0.2%						5.2%
Unknown				0.3%									0.3%

117 This data stems from the analysis in chapter X on the geographic origin of the supply. The import of agricultural biomass was not included in the biomass questionnaire part of the NECPRs.

When considering the environmental impacts of biofuel production, various feedstocks bring about different environmental impacts. Please note that the environmental risks discussed below are general and linked to the cultivation of the specific feedstock and is not reserved only for the production of biofuels. This section derives key insights regarding the environmental impacts of feedstocks commonly used for biofuel from Section 4.2 and provides a further overview of impacts in Table 16.

Rapeseed has a relatively high domestic cultivation with 77% of the rapeseed originating from the EU. Of the total land area that is required for the EU biofuels market, 53% is for rapeseed cultivation (4,596 kha).[118] Compared to other oil crops, rapeseed has a relatively low biodiversity risk. Conversion efficiency of rapeseed to biofuel (kg biofuel per kg feedstock) is high, but rapeseed has a relatively low yield, especially when compared to oil palm, so it has a relatively low area efficiency. Biofuels that are produced from rapeseed feedstocks have typical GHG emission savings of 51 – 59 % (Annex V of REDII).

All palm oil is imported from outside the EU. Combined, Indonesia and Malaysia are responsible for 16.5% of the feedstocks that are used for the EU biodiesel & biogasoline markets. Although palm oil yields have the highest area yields of oil crops, palm oil is a high ILUC-risk feedstock[119], has a high impact on water quality due to its palm oil mill effluent (POME)[158,159], and has a very high biodiversity risk (due to high rates of deforestation for the crop as a whole)[120, 121]. Palm is currently the only feedstock classified as high ILUC-risk, according to the criteria included in the Delegated Regulation (EU) 2019/807 and RED II, and therefore it needs to be phased out by 2030, unless it is low ILUC-risk certified.[122] Several MSs (France, Austria, Germany) have already excluded palm oil as a feedstock that can count for the calculation of their gross final consumption of energy from renewable sources towards the RED II targets, or are speeding up the phase out trajectory (Italy), as described in 3.2. Typical GHG emission savings for biofuels that are based on palm oil are in the range from 32 – 59 % (Annex V of REDII). Due to a lack of trend data reported by MS regarding the split between high- and non-high ILUC-risk feedstocks (only data for 2021), no quantitative trends or potential policy impacts can be derived at this stage.

Soy is another feedstock of which 87% is imported into the EU. Soy is mainly produced for its protein meal content (for human and animal consumption) and therefore requires a lot of land to produce oil yield. The REDII rules (including the sustainability and GHG emissions savings criteria) have to be respected if soy is used for the production of biofuels. Typical GHG emission savings for biofuels that are based on soy feedstocks are in the range of 55–63% (Annex V of REDII).

Only small amounts of biofuels produced from sugar cane are consumed in the EU (although 100% imported), and the total estimated required land use to produce biofuels is small (10 kha). Sugar cane has high pollution risks from processing[123] and its high fertilizer demand increases associated environmental risks[124]. Furthermore, sugar cane has a low kg biofuel per kg feedstock ratio, but typical GHG savings for biofuels based on sugar cane are higher than the oil crops, at around 70% (Annex V of REDII).

Finally, Annex IX feedstocks are mostly waste or residue based, which makes their environmental impacts lower than (main) crops, as they do not have environmental impacts or GHG emissions associated with land use or cultivation. Article 29(2) of REDII requires that agricultural residues (such as straw) *are only used where there are management plans*

118 See section 2.4.2
119 Meijaard, E. et al. (2018). Oil palm and biodiversity. https://doi.org/10.2305/IUCN.CH.2018.11.en
120 Our World in Data. (2022). Palm Oil. https://ourworldindata.org/.
121 WUR, Indonesian deforestation and palm oil plantation expansion slows down. (2022). https://www.wur.nl/.
122 Delegated Regulation 2019/807.
123 Omprakash Sahu (2018) Assessment of sugarcane industry: Suitability for production, consumption, and utilization. https://doi.org/10.1016/j.aasci.2018.08.001
124 Rathnappriya, R. H. K., Sakai, K., Okamoto, K., Kimura, S., Haraguchi, T., Nakandakari, T., Setouchi, H., & Bandara, W. B. M. A. C. (2022). Examination of the Effectiveness of Controlled Release Fertilizer to Balance Sugarcane Yield and Reduce Nitrate Leaching to Groundwater. https://doi.org/10.3390/agronomy12030695

in place to address impacts on soil quality and soil carbon, to ensure that such feedstocks are not over-harvested at the expense of soil fertility. Typical GHG savings from biofuels originating from waste and residues, according to the relevant values included in Annex V of REDII, are above 80% (e.g., 88% for UCO based biodiesel, 84% for animal fat biodiesel, 85% for straw-based ethanol). Annex IX feedstocks do have alternative uses as elaborated on in chapter 4.4 and 4.5. Also, please note that Annex IX B feedstocks were involved in some fraud cases, as reported in chapter 3.3.

Table 16: Overview of environmental impacts of several key feedstocks

Biofuel feedstock	Import dependency	Range of GHG savings (typical value REDII Annex V)	Land use	Main potential environmental risks	Other reflections
Rapeseed	77% of rapeseed produced in EU	51 – 59 %	4,596 kha	1.2 kg CO2e/MJ Relatively low biodiversity risk compared to other oil crops (1 IUCN[125] red list species threatened by crop) Relatively low area efficiency. If expanded, more area would need to be occupied (0.7-1.8 t/ha) If sourced within EU, covered by CAP (Germany one of the largest producers globally)	
Palm oil	All feedstock is imported	32 – 59 %	643 kha	1.2 kg CO2e/MJ POME risks, high pollution risk from processing Very high biodiversity risk, estimated 321 species threatened by crop (from IUCN red list) Highest area yields of oil crops: less area needed to produce oil (1.9-4.8 t/ha) Perennial cropping system (larger land occupancy)	Identified as high ILUC-risk crop
Soy	87% of feedstock is imported	55 – 63 %	1,798 kha	1.3 kg CO2e/MJ Relatively high biodiversity risk (73 species from IUCN red list threatened by crop) Low yielding. If expanded, higher threat of land use change. (0.4-0.8 t/ha)	

125 IUCN refers to the International Union for Conservation of Nature

Sugar cane	All feedstock is imported (from one country: Brazil)	70 %	10 kha	High pollution risk from processing Perennial cropping system (higher land occupancy) High fertilizer demand increases associated risks	
Annex IX A	Various feedstocks	85 – 89 %	-	Waste and residues, which are therefore likely to have low environmental impacts	Limited competition
Annex IX B	All animal fat has EU origins, UCO for 44% from EU origins	83 – 98 %	-	Waste and residues, which are therefore likely to have low environmental impacts	Capped in REDII

Multiple policy packages are adopted by co-legislators that specify minimum or maximum levels of certain types of biofuels as described in chapter 3.1. REDI and REDII incentivise the use of Annex IX (especially Part A) biofuels, by use of multipliers, targets, and caps. Supply of and demand for Annex IX biofuels is increasing. In 2021, consumption of Annex IX Part B biofuels was still higher than consumption of Annex IX Part A biofuels. However, the growth rate of Annex IX Part A biofuels is higher. This growth can, in part, be connected to the RED policies.

In contrast, policy incentives are moving away from food and feed biofuels. Use of food and feed biofuels is still allowed, but the RED limits the contribution of biofuels produced from feed and food crops towards decarbonisation of the transport sector; their share, consumed in the transport sector, is capped at a specific level per MS, as was introduced by the ILUC Directive and the REDII[126]. Since 2020, EU demand of food and feed biofuels has experienced a decreasing trend, as presented in Section 2.3.1. This decrease could indicate that the food and feed caps in the RED and ILUC Directive are providing a signal to the market, which is picked up in the desired manner.

Conclusion

Biodiesel is the biofuel that is most widely used in the EU. It is mainly produced from domestically cultivated rapeseed, which has relatively low environmental impacts. Other oil seeds grown in the EU have a very limited use for biodiesel currently. However, the second largest feedstock to produce biodiesel is palm oil, for which all feedstock is imported. Palm oil has a very high yield compared to other oil seeds, so it has a high area efficiency. However, it is associated with high risks of land use change and is classed as a high ILUC-risk feedstock. Palm oil currently contributes 14% EU biodiesel and this gap will need to be filled by alternative feedstocks. As palm yield is typically two to three times higher than other oil seeds, this gap could be significant.

Bioethanol currently comes mostly from EU-produced sugar beet, corn, and wheat (16.1%) with 1.4% from other EU grown crops. Sugar cane is 100% imported, but only contributes 0.2% of bioethanol.

126 According to Article 26 (1) of the Renewable Energy Directive, *the share of biofuels and bioliquids, as well as of biomass fuels consumed in transport, where produced from food and feed crops,* ***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.*

Import dependency

The feedstocks with a risk of high import dependency on non-EU suppliers are palm oil, soy, UCO, sugar cane, and wood pellets. Palm oil is 100% imported, primarily from Indonesia (65%) and Malaysia (29%). Meanwhile, 87% of soy is imported, mostly from Brazil (46%), the USA (24%), and Argentina (21%). UCO is 56% imported, mainly from China (37%), Malaysia (13%), and Indonesia (11%). 100% of sugar cane is imported from Brazil. Finally, 34% of wood pellets are imported from Russia (35%) and the USA (33%). These feedstocks however are not the major feedstocks used in their respective bioenergy categories. Palm oil makes up 15% of the total liquid biofuels in the EU in 2021, sugar cane makes up 1% of the total bioethanol, (see section 2.2.1). Wood pellets make up 9% of the total forest biomass used for energy[127]

4.2. The impact of the production or use of biofuels, bioliquids and biomass fuels on biodiversity, water, soil and air quality in the Union and other sourcing regions

MSs are requested to report local environmental impacts related to the use and production of biofuel, bioliquids, and biomass fuels on water, air, soil quality, and biodiversity in their Progress Reports.

4.2.1. Findings of Member State reports

Most countries did not report any information on environmental impacts related to biofuel, bioliquids, and biomass fuels. The Netherlands and Spain reported that environmental impacts are negligible because the production of crops for biomass fuels is minimal. Estonia and Hungary reported environmental impacts related to forest management, focusing on limiting biodiversity impacts of wood harvesting. Malta and Slovenia report positive air quality trends and Sweden states possible impact on soils due to acidification, nutrient loss, and carbon fluxes.

Since MSs provided limited information related to the environmental impacts in the Union and sourcing regions outside the EU, this section has been complemented by two elements to generate some additional insights in potential local environmental impacts related to biomass production:

- Potential environmental impacts from crop-related biomass production based on estimated sourcing and consumption of the MS
- Potential future developments

In the first section, we summarize our findings on environmental impacts related to main feedstock types used for biofuel, bioliquids, and biomass fuels. This section focuses on the biomass sources with highest direct potential environmental impacts, namely crop-based biomass. The categories of wastes and residues (most of the solid biomass and biogas feedstock types) are left out of scope for this section since these are to a lesser extent related with environmental impacts.

Since the amount of biofuels produced from food and feed crops is capped under REDII and there is an increased focus towards 2030 on advanced biofuels, we have added the second section on potential future developments.

4.2.2. Environmental impacts from crop-related biomass production

Under the REDII, the EU aims to increase the share of renewable energy, including biofuels, in the transport sector to at least 14% (by energy content) by 2030.[128] In this section, the

127 Source: Eurostat Supply of biomass - annual data (NRG_CB_BM)
128 European Commission. (2023). Biofuels. https://energy.ec.europa.eu/.

environmental risks relating to air, water, soil quality, and biodiversity have been assessed based on literature for the main crops and country of origin combinations used for biofuel consumption in the EU in 2021.[129] **The assessment below is not biofuel-specific and therefore no impacts should be directly attributed to the use of these crops for the production of biofuels. The impacts described are general environmental impacts associated with the cultivation of the crop, regardless of its end-use.**

Impacts from rapeseed, wheat, maize, and sugar beet cropping in the EU are described together due to their interconnection. It is worth noting that the risks described here apply generally to these crop-country combinations and are not biofuel specific. It is hard to distinguish between sustainability impacts from biofuel crop production and non-biofuel crop production. For one, because different components of crops are used for multiple purposes; often crop residues and "additional" yields of a crop are used for biofuel production. This means that biofuel crops can even come from the same field as other crop products. In addition, crops used for biofuel are cultivated within the same farming systems as "regular" crops, which makes distinguishing the effects resulting from biofuel crop production and from crops within the same crop system difficult, perhaps even impossible, to analyse. Lastly, environmental impacts vary across crop types, agroecological regions, soil conditions, and even within countries. The EU biofuel sustainability criteria aim to limit environmental impacts from biofuel production and vice versa can even positively impact wider crop production if the same sustainability criteria or certification schemes are applied to crops that are not grown for biofuels.

There are currently 15 international and national voluntary schemes recognized by the European Commission, for compliance with the RED II rules for forest and agricultural biomass. Out of these 15 schemes, the 14 cover (also) agricultural biomass and can ensure the REDII mandatory sustainability criteria are met. As set out in the REDII, certifications must cover the below basic criteria for agricultural biomass:

- Article 29(2) limits the impact on soil quality and soil carbon of harvesting of agricultural wastes and residues.
- Article 29 (3) - (5) cover the protection of land with a high biodiversity value and protection against conversion of high-carbon stock land and peatlands[130].
- Article 29 (10): greenhouse gas emissions savings requirements.

In addition, many of the voluntary schemes also include broader sustainability criteria related to, for example, soil, water, air, broader biodiversity measures, or even social measures. Table 17 below gives an overview of the extent to which the recognized voluntary schemes include such broader sustainability requirements and lists their crop and geographical coverage. Note that even the schemes that do not include explicit mandatory broader sustainability criteria (marked as 'x' in the table), sometimes include broader criteria as recommendations (e.g. 2BSvs) or explicitly make reference to good agricultural practices or, for crops cultivated in the EU, ensuring compliance with the CAP criteria.

129 See section 2.4.1 for further information.

130 These criteria are relevant for agricultural biomass. Under RED II, sustainability criteria have also been introduced for forest biomass. Fuels originating from forest biomass, in order to be considered towards the targets and receive subsidies, also have to comply with the RED II rules (among which the sustainability and GHG emissions saving criteria) and to be certified as such. Specifically for forest biomass, Article 29 (6) – (7) includes harvesting and LULUCF-related sustainability criteria.

Table 17: Overview of recognised certification schemes for agricultural biomass, recognised by the EC under REDII

Certification	Additional sustainability criteria				Crop coverage	Regional coverage
	Soil	Water	Air	Biodi-versity		
Biomass Biofuels voluntary scheme (2BSvs)					Agriculture crops	Global
Better Biomass	x	x	x	x	Agriculture crops	Global
Bonsucro EU	x	x	x	x	Sugar cane	Global
International Sustainability and Carbon Certification (ISCC EU)	x	x	x	x	Agriculture crops	Global
KZR INiG system					Agriculture crops (also covers forestry)	Global (primarily Poland)
REDcert*	(x)	(x)			Agriculture crops	Global
Red Tractor Farm Assurance Combinable Crops & Sugar Beet Scheme (Red Tractor)	x	x		x	Cereals, rape seed & sugar beet	UK
Roundtable of Sustainable Biofuels EU RED (RSB EU RED)	x	x	x	x	Agriculture crops	Global
Round Table on Responsible Soy EU RED (RTRS EU RED)	x	x	x	x	Soy	Global
Scottish Quality Farm Assured Combinable Crops (SQC)**		x		x	Cereals & rape seed	UK
Trade Assurance Scheme for Combinable Crops (TASCC)**	n/a	n/a	n/a	n/a	Cereals, rape seed & sugar beet	UK
Universal Feed Assurance Scheme (UFAS)**	n/a	n/a	n/a	n/a	Cereals, rape seed & sugar beet	UK
Sustainable Resources (SURE) voluntary scheme	x	x			Agriculture crops (also covers forestry)	Global
Austrian Agricultural Certification Scheme (AACS)					Agriculture crops	Austria
Sustainable Biomass Program (SBP)***	x	x	x	x	Only forestry	Global

*REDcert relies on EU cross compliance, based on the CAP, as proof of additional soil and water requirements for products produced in the EU. Outside the EU auditors are required to monitor compliance with the criteria.
**The TASCC and UFAS schemes cover chain of custody only and rely on other voluntary schemes to certify sustainable feedstock production at the farm level.
***SBP recognition under the REDII is limited to forestry and thus doesn't include agricultural biomass.

A literature review was conducted to understand the past and present impacts of crops commonly used for biofuel production. No distinction could be made between the end use of the crop (i.e. biofuels or other purposes) in the review, as literature does not distinguish. A summary of environmental impacts from all literature used in the chapter can be found in Table 18. Detailed descriptions of the environmental impacts of crops are in the following sections.

Table 18: Overview of environmental impacts of crop-country combinations, selected based on estimated sourcing and consumption of the EU Member States

	EU	Indonesia & Malaysia	Brazil, Argentina, & USA
	Rapeseed, wheat, maize, sugar beet	*Palm oil*	*Soy*
Water	• Pollution of water bodies through fertilization and agrochemical use • Eutrophication drives aquatic biodiversity loss	• Water pollution from leaching, soil erosion, and effluent discharge of palm oil processing facilities • Destruction of ecosystems through eutrophication and acidification	• Eutrophication of water bodies through run-off and leaching of fertilisers • Pollution of water bodies through pesticides
Soil	• Increased soil erosion and compaction due to intensive agricultural practices • Loss of soil organic matter and reduced soil fertility • Soil contamination due to pesticide use and soil acidification reduce biodiversity and increase GHG emissions	• Soil erosion and reduced soil fertility through palm oil cultivation in intensive agriculture • Reduced soil fertility, leaching, and increased erosion from unsustainable fertilizer use • Disturbed microclimates increase erosion risk and prevalence of fires	• Soil erosion and reduced soil fertility through soybean cultivation in intensive agriculture • Disturbed water filtration, drainage, and nutrient cycling
Air	• Air pollution due to manure-based fertilizers and use of agrochemicals drives health risks	• Air pollution through fire haze and increased erosion • Methane pollution from palm oil processing pollutants	• Air pollution through burning of crop residues, as well as other waste and methane emissions • Increased likelihood of dust storms and erosion
Biodiversity	• Intensive agriculture drives habitat loss and fragmentation • Reduced genetic diversity inhibits climate adaptation of ecosystems and agriculture	• Decreased habitat and resources for wildlife • Increased risk of habitat loss due to forest fires • Human-wildlife conflicts • Loss of local biodiversity through intensive agriculture	• Habitat loss through indirect displacement effects • Loss of local biodiversity through intensive agriculture

Rapeseed, wheat, maize, and sugar beet

The crops grown to produce biofuels in the EU are mainly rapeseed, maize, wheat, and sugar beet. Together with soy and palm oil, these food and feed crops accounted for 93%[131] of bioethanol blended with gasoline and 55% of biodiesel in the EU.[129] Only half of the EU biofuel crop demand is grown domestically.[129] The crop-based biofuel consumption varies between EU MSs (Figure 38). For instance, in Germany, palm oil is the largest biofuel energy source, whereas France consumes more biofuel based on rapeseed. In

131 Analysis in this report has a varying figure due to part of bioethanol sourcing origins being unknown. See section 2.2.1 for further information.

total, rapeseed is the largest energy crop grown and used for biodiesel domestically, followed by maize and wheat, which are used in bioethanol production.[132]

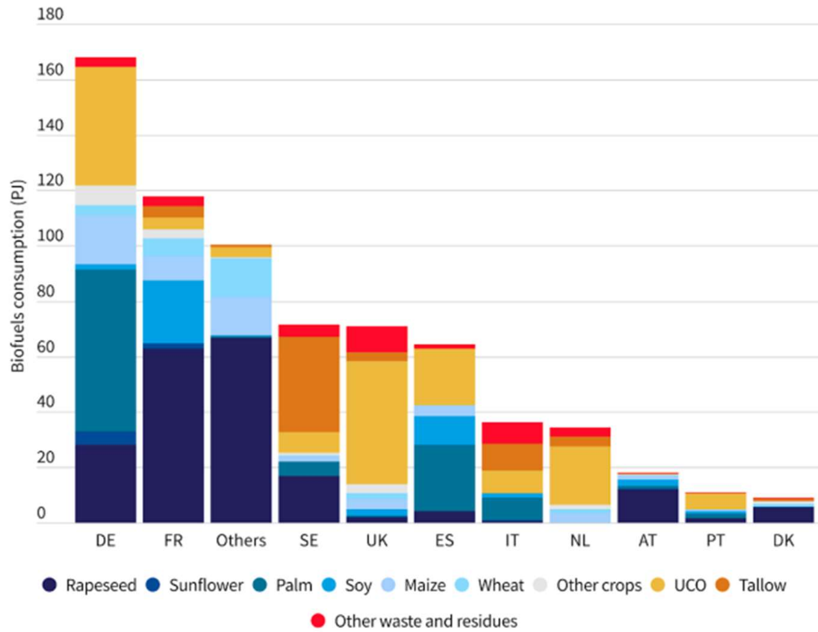

Figure 38: Biofuel volumes by feedstock and country consumed in the EU in 2020. Source: IFEU (2023)

Countries are mandated by the REDII to report on their national renewable energy developments including impacts on biodiversity, air, soil, and water quality. Since EU agriculture production is regulated by common environmental regulations and programs, such as the EU's Common Agriculture Policy (CAP), it can be expected that the environmental impact of biofuel crop production is the same as non-biofuel crop production. Where possible, the sections below provide insights into the specific impacts of crops used for biofuel and describes related environmental impact of crop production in the EU. The impacts described below are not solely driven by biofuel crop production and therefore no impacts should be directly attributed to the use of these crops for the production of biofuels. Nonetheless, impacts from "general" crop production are described as the impacts from production of biofuel crops is indistinguishable from "general" crop production.

The largest producers of cereals (including crops used for biofuel, namely wheat and maize) and rapeseed in the EU are France and Germany, followed by Poland and Spain (not for rapeseed).[133] Sugar beet is mostly cultivated in France, Germany, the Netherlands, Belgium, and Poland.[133] Intensive agricultural production is common for maize, rapeseed, sugar beet, and wheat farming in the EU.

Water Quality

A major cause of poor water quality in some parts of the EU is the use of pesticides and fertilizers.[134] Under the European Green Deal there are multiple initiatives aimed at steering and preventing water quality issues, including a target to reduce the loss and risks of nutrients and pesticides by 50% until 2030.[135]

132 IFEU. (2023). The Carbon and Food Opportunity Costs of Biofuels in the EU-27 plus the UK. https://www.transportenvironment.org/.
133 European Commissions (2023) Agri-food Data Portal. https://agridata.ec.europa.eu/
134 European Environment Agency. (2021). Water for agriculture. https://www.eea.europa.eu/.
135 European Environment Agency. (2021). Drivers of and pressures arising from selected key water management challenges. https://www.eea.europa.eu/.

Nutrients and pesticides enter water bodies through erosion, surface run-off, leaching, and polluted drainage and negatively affect aquatic ecosystems and human health.[134] 22% of surface water bodies and 28% of groundwater area pollution is linked to agriculture in the EU and is reportedly leading to failure of ecological and chemical statuses in water bodies.[134,135] Maize, sugar beet, rapeseed, and wheat cropping make considerable contributions to pollution, as these crops have the highest fertilizer demands and face significant pest pressure requiring agrochemical use in intensive agricultural systems.[136]

Nitrogen and phosphorus pollution from fertilizer use is a major cause of pollution and leads to eutrophication in water bodies, which can harm or even lead to the destruction of natural ecosystems. Currently, there is an estimated surplus of 27 million tons of nitrogen per year in the EU.[135] The combined effect of agrochemicals from pesticide application entering aquatic systems are still unclear, but this can affect entire trophic chains with expected wide scale impacts. Recent trends show improved wastewater treatment and reductions in agricultural inputs has led to decreasing nitrate concentrations in rivers.[135]

The EU and individual MSs have identified and implemented measures to reduce water pollution linked to agriculture. Measures include restricted organic fertilizer application on fields as described in the Nitrogen Directive. In addition, application of mineral and organic fertilizers is limited by amounts and application techniques, as well as timing to reduce leaching. In addition, the Farm to Fork Strategy incorporates nutrient management plans to reduce fertilizer use by 20% by 2030.[137] However, key pollution challenges still persist in hotspot regions in all EU MSs[138] with intensive agricultural production where high nutrient loads and unbalanced nutrient application overburden natural ecosystems. For instance, the EC lawsuit against Germany over its failure to comply with EU laws due to excessive nitrate levels in its groundwater was dropped in 2023.[139]

Soil Quality

The intensive production of maize, rapeseed, sugar beet, and wheat negatively impacts soil health and fertility, which is critical to the environment and economic production.[134] In fact, on average, 2.5 tons of soil are lost annually per hectare in the EU, compared to 1.4 tons per hectare soil formation.[140] These high erosion levels risk future production of biofuels and food crops. It is predicted that globally, food productivity could be reduced by 12% in the next 25 years due to soil degradation.[134]

Intensive practices drive degradation of soils in various ways. For example, heavy machinery compacts soil, monocultures damage soil biodiversity and soil structures in the long term, the intensive use of agrochemicals pollute soils, and the reliance on mineral fertilizers has led to the neglect of soil organic matter contents of soils.[141] These factors contribute to long-term reduced yields, disturbed water cycling, reduced biodiversity, heightened soil greenhouse gas emissions, desertification, and salinization and acidification of soils across Europe.[142] Unsustainable land management practices have led to the degradation of 60-70% of soils in the EU, meaning soils have at least partially lost the capacity to provide ecosystem services.[143]

One of the main drivers of soil degradation is the loss of soil organic matter (SOM) content, which fuels the reliance on mineral fertilizers[136], especially for maize, sugar beet, rapeseed, and wheat, which require high nutrient input in intensive systems. SOM is also crucial to

136 FAO. (2023). Fertilizer consumption by crop. https://www.fao.org/.
137 European Commission (2020) Farm to Fork Strategy. https://food.ec.europa.eu
138 European Commission. (2021). Zero pollution: Commission report shows more needs to be done against water pollution from nitrates. https://ec.europa.eu/.
139 Tagesschau. (2023). EU-Verfahren gegen Deutschland eingestellt. https://www.tagesschau.de/.
140 European Environmental Agency. (2022). Rethinking Agriculture. https://www.eea.europa.eu/.
141 European Commission. (2023). Healthy soil. https://agriculture.ec.europa.eu/s.
142 Peter M. Kopittke, Neal W. Menzies, Peng Wang, Brigid A. McKenna, Enzo Lombi. (2019). Soil and the intensification of agriculture for global food security. https://doi.org/10.1016/j.envint.2019.105078.
143 Carla S.S. Ferreira, Samaneh Seifollahi-Aghmiuni, Georgia Destouni, Navid Ghajarnia, Zahra Kalantari. (2022). Soil degradation in the European Mediterranean region: Processes, status and consequences. https://doi.org/10.1016/j.scitotenv.2021.150106.

water retention of soils,[136] which is becoming increasingly important given longer drought periods experienced across Europe due to climate change.[144]

Intensive agriculture and long-term cropping also cause significant GHG emissions as mineralization causes SOM in topsoil to decrease. In the EU, over 31 megatons of CO_2 equivalent were released in 2019 from croplands.[145] The over-application of nitrogen fertilizers also causes leaching, which leads to acidification of soil and consequently, reduced soil fertility.[136]

The EU has installed multiple programs to address soil health as part of the CAP and the European Green Deal, which includes the Farm to Fork Strategy, the Zero Pollution Action Plan, EU Soil Strategy, and the Organic Action Plan.[135] However, a recent audit report finds that the EU policies and funding require improvement and areas with prominent soil issues need to be targeted further.[146]

Air Quality

Poor air quality negatively affects human health, can reduce agricultural productivity, and impacts ecosystem functioning. Intensive agriculture in the EU negatively impacts air quality through the spreading of manure and application of agrochemicals, especially on uncovered soils, which increase the occurrence of particulate matter. 95% of ammonia emissions in the EU are linked to livestock farming and the use of mineral nitrogen fertilizers, as used in intensive production of biofuel crops including maize, rapeseed, sugar beet, and wheat.[142] When ammonia reacts with other pollutants in the athmosphere, it forms particulate matter

The CAP targets agricultural practices that reduce air quality to warrant compliancy with the EU clean air policies and commitments of the National Air Pollution Control Programmes.[142]**Error! Bookmark not defined.** However, intensive agricultural production and air pollution remain interlinked, as a study has found that by increasing agricultural output by 20% excess mortality rates also increase by 24% in the EU.[147]

Biodiversity

Habitat loss and fragmentation linked to unsustainable agriculture practices are drivers of biodiversity loss on a global scale. Intensive agriculture, as commonly practiced for biofuel crops like maize, wheat, sugar beet, and rapeseed, is increasing biodiversity loss in the EU.[148] Only 3% of key species that are dependent on agriculture are in a favourable conservation status[149], whereby 50% of all species in the EU are dependent on agricultural habitats.[150]

In intensive agriculture, farmers commonly specialize in certain crops to focus on high-output farming systems. This requires increased use of chemicals and machinery and causes less diverse landscapes due to monocropping and reduced soil health, which ultimately disturbs species occurrence and densities compared to natural ecosystems. Homogenous landscapes lacking hedges, trees, grass, shrubs, and ponds do not provide habitats to support biodiversity.[148]

Reducing field sizes and diversifying cropping patterns can create more diverse landscapes while maintaining cropland productivity under conventional farming practices.[151] However,

144 European Commission. (2022) Copernicus: European State of the Climate 2022 Unprecedented extreme heat and widespread drought mark European climate in 2022. https://climate.copernicus.eu/.
145 European Environment Agency. (2022). Soil Carbon. https://www.eea.europa.eu/p.
146 European Court Of Auditors. (2023). Soil protection: EU most roll up its sleeves. https://www.eca.europa.eu/.
147 Iias Giannakis, Jonilda Kushta, Despina Giannadaki, George K. Georgiou, Adriana Bruggeman, Jos Lelieveld. (2019). Exploring the economy-wide effects of agriculture on air quality and health: Evidence from Europe. https://doi.org/10.1016/j.scitotenv.2019.01.410..
148 European Court of Auditors. (2019). Biodiversity in farming. https://www.eca.europa.eu/.
149 European Environment Agency. (2015). EU 2010 biodiversity baseline. https://www.eea.europa.eu/.
150 European Commission (2023) Enhancing agricultural biodiversity. https://agriculture.ec.europa.eu/
151 Tscharntke, T., Grass, I., Wanger, T.C., Westphal, C. and Batáry, P. (2021). Beyond organic farming–harnessing biodiversity-friendly landscapes. https://doi.org/10.1016/j.tree.2021.06.010.

large field sizes are economically more efficient as working time and fuel expenses are lower.[152]

A lack of biodiversity reduces an ecosystem's ability to adapt due to lower genetic diversity in reduced populations, which is crucial to resilience in shifting environmental conditions, as fostered by climate change.[144] Agricultural systems rely on biodiversity for ecosystem services such as pollution, maintenance of soil fertility, and genetic diversity provides possibilities to genetic resistance to pests and diseases.[146]

Past studies have shown that EU agriculture policies have had little impact on increasing biodiversity by limiting the use of pesticides.[153] The CAP 2023-2027 has laid a stronger focus on biodiversity protection than previously. For instance, targets include that 10% of agricultural area should be placed under high-diversity landscape features and the Natura2000 network shall be expanded to protect 30% of EU land. Likely, additional sustainbility criteria of schmes covered under REDII can have a posititve impact.

Palm Oil

The oil palm tree grows in tropical regions in Asia, Africa, and South America. Initially, palm oil was cultivated mainly for use in the food industry, but since 2010 its energetic use has increased. By 2018, 53% of imported palm oil in the EU was used for biodiesel.[154] Since then, the EU has taken legislative action, most recently with the REDII, which sets to phase out the use of crops with high risk of indirect land use change (high ILUC-risk) for energy use by 2030. Currently, palm oil is classified as high ILUC-risk and will need to be phased out for biofuel by 2030, unless it is certified as low ILUC-risk. Malaysia and Indonesia are currently the largest importers of palm oil to the EU. In total, the EU imported 6.5 million metric tons of palm oil in 2021, of which 45% were from Indonesia and 25% from Malaysia.[155] The EC expects crop-based biodiesel demand to shrink, both due to the high ILUC-risk phase out and the cap on biofuels from food and feed crops.[154,155]

Replacing palm oil with other feedstocks needs to be assessed with caution, as palm oil produces up to nine times more oil per area compared to other oil crops. Shifting crop use while maintaining demand may lead to displacement effects including land-use change.[156]

The Directive sets a target to limit the use of feedstocks that are considered to have high ILUC-risk to 2019 levels and completely phase out their use by 2030, unless they are certified as low ILUC-risk. Low ILUC-risk feedstocks need to prove they are produced using "additional biomass" which can stem from additional yields from existing agricultural cropping systems or new crop production if it occurs on formerly unused, abandoned, or severely degraded land.[157] As a result, low ILUC-risk certified feedstocks should prove they do not displace existing production.

In the following section, the analysis focuses on how existing palm oil plantations affect the environment. Currently, supply chain transparency of palm oil use specifically for biofuel is still lacking due to its complexity, hence standard agricultural practices and risks to the environment in Indonesia and Malaysia will be considered.

---

152 Clough, Y., Kirchweger, S. and Kantelhardt, J. (2020). Field sizes and the future of farmland biodiversity in European landscapes. https://doi.org/10.1111/conl.12752.

153 Iavia Geiger, Jan Bengtsson, Frank Berendse, Wolfgang W. Weisser, Mark Emmerson, Manuel B. Morales, Piotr Ceryngier, Jaan Liira, Teja Tscharntke, Camilla Winqvist, Sönke Eggers, Riccardo Bommarco, Tomas Pärt, Vincent Bretagnolle, Manuel Plantegenest, Lars W. Clement, Christopher Dennis, Catherine Palmer, Juan J. Oñate, Irene Guerrero, Violetta Hawro, Tsipe Aavik, Carsten Thies, Andreas Flohre, Sebastian Hänke, Christina Fischer, Paul W. Goedhart, Pablo Inchausti. (2010). Persistent negative effects of pesticides on biodiversity and biological control potential on European farmland. https://doi.org/10.1016/j.baae.2009.12.001.

154 European Federation for Transport and Environment. (2023). Palm oil and global warming. https://www.transportenvironment.org/.

155EC. (2021). EU agricultural outlook for markets, income and environment, 2021-2031. https://agriculture.ec.europa.eu/.

156 Meijaard et al. (2018). Oil palm and biodiversity. A situation analysis by the IUCN Oil Palm Task Force. IUCN Oil Palm Task Force Gland, Switzerland: IUCN.

157 ILUC- High and low ILUC-risk fuels. (2023) The RED II. https://iluc.guidehouse.com/.

Water Quality

Conventional and intensive palm oil cultivation can cause water pollution with negative effects on ecosystem services. Local populations can be affected by reduced water availability and lack of drinking water quality. In Indonesia and Malaysia, large amounts of fertilizers and pesticides are used for palm oil cultivation, which leach and pollute water bodies. Soil erosion is also increased in intensive production systems and contributes to decreased water quality when dust enters aquatic systems. However, the largest pollution risk stems from palm oil mill effluent (POME), an oily wastewater consisting of various suspended components, which is often discharged into water bodies and leads to the degradation of aquatic systems harming plants, wildlife, and impacting human health.[158] Per ton of produced crude palm oil, up to 7.5 tons of water are used, of which half becomes POME.[159] Considering Indonesia produced 46 million tons[160] and Malaysia 18 million tons[161] of crude palm oil in 2021, very large amounts of POME are produced. The REDII encourages the proper treatment of POME via the greenhouse gas saving criteria. In the Annex V default values, a separate default value is included for palm biodiesel with an open effluent pond and palm biodiesel with methane capture from POME at the oil mill. Without methane capture, it would be essentially impossible to meet the required GHG saving for biofuel.

In an effort to limit pollution, Malaysia and Indonesia have implemented discharge standards to reduce effluents reaching natural water bodies. A large amount of palm mills in Indonesia do not meet these standards[162], even though POME effluent discharge limits are below Malaysian standards, where the majority of facilities are compliant.[163] POME contains high levels of biochemical and chemical oxygen demand, nitrogen, and phosphorus, leading to eutrophication and acidification of water bodies.[166] Cleaning discharge water is costly, which incentivizes unfiltered discharge into nearby streams and rivers. The ISSC[164] certification guidance, incentivises POME treatment, as oil recovered from POME 'is considered to have zero GHG emissions' at mill level.[165]

Due to the large scale of the issue, there have been efforts for cost-effective systems to reduce the impact of contaminants in the soil and groundwater. Here, pond and land application techniques are used by industry to treat POME and reduce its environmental impact before being discharged into the environment.[166] One promising innovation is the use of constructed wetland to reduce POME, where planting systems of *Scirpus grossus*, a perennial herb, is used to "polish" POME.[167]

Soil Quality

Soil quality and health are negatively affected in areas of palm oil cultivation in Indonesia and Malaysia. One of the main drivers of soil decline is land-use change, as deforestation or destruction of peat land drastically reduces soil organic carbon and plant diversity. However, further land-use changes are limited under the REDII and going forward the

158 Maria Vincenza Chiriacò et al. (2022). Palm oil's contribution to the United Nations sustainable development goals: outcomes of a review of socio-economic aspects. https://iopscience.iop.org.
159 Wai Yan Cheah, Razman Pahri Siti-Dina, See Too Kay Leng, A.C. Er, Pau Loke Show. (2023). Circular bioeconomy in palm oil industry: Current practices and future perspectives. https://doi.org/10.1016/j.eti.2023.103050.
160 Stockholm Environment Institute. (2023). Indonesia makes progress towards zero palm oil deforestation. https://www.sei.org/.
161 Statista. (2023). Production of crude palm oil in Malaysia from 2012 to 2021. https://www.statista.com/.
162 Saputera WH, Amri AF, Daiyan R, Sasongko D. (2021). Photocatalytic Technology for Palm Oil Mill Effluent (POME) Wastewater Treatment: Current Progress and Future Perspective. https://doi.org/10.3390/ma14112846.
163 Osman et al. (2020). The effect of Palm Oil Mill Effluent Final Discharge on the Characteristics of Pennisetum purpureum. https://doi.org/10.1038/s41598-020-62815-0.
164 The ISSC certification scheme is one of the main certification bodies for compliance with REDII sustainability criteria.
165 ISSC. (2022). ISSC Guidance Watse and Residues form Palm Oil Mills. https://www.iscc-system.org/.
166 Mohammad S, Baidurah S, Kobayashi T, Ismail N, Leh CP. (2021). Palm Oil Mill Effluent Treatment Processes. A Review. https://doi.org/10.3390/pr9050739.
167 Maryam 'Aqilah Norhan, Siti Rozaimah Sheikh Abdullah, Hassimi Abu Hasan, Nur 'Izzati Ismail. (2023). A constructed wetland system for bio-polishing palm oil mill effluent and its future research opportunities. https://doi.org/10.1016/j.jwpe.2021.102043.

recently approved EU regulation on deforestation-free products, will require traders importing soy to the EU for any end-use purposes to prove "that the products do not originate from recently deforested land or have contributed to forest degradation".[198]

Palm oil plantations have much lower erosion control potential than the natural forest. Plantations are largely planted in monoculture systems where plant diversity is low and soil coverage is limited, vegetation cover protects natural ecosystems from erosion. Eroded soil often enters water bodies, which pollutes local water supplies and causes nutrients to leach into the water bodies, leading to river constriction. This, in turn, threatens aquatic ecosystems.[168] Soils also lose organic matter due to erosion, which is critical for healthy soils and fundamental to soil ecosystem services, such as climate regulation and water storage.

Intensive agricultural practices in oil palm cultivation, such as high fertilizer and pesticide usage, heighten soil damage and negatively impact local ecosystems. For instance, herbicides are used in palm oil plantations to remove weeds. However, this causes more soil to be barren and vulnerable to erosion and additionally poisons local wildlife.[169] Soils become increasingly depleted of nutrients when removing organic matter, which acts as a slow-release fertilizer. The nutrient gap is then filled by using mineral fertilizers, which increases nutrient leaching[168] as their compounds are more volatile. For instance, groundwater near plantations shows high nitrate concentrations due to nitrogen fertilizer application.[168] Traditionally, plant materials are burnt to remove unwanted material and replenish depleted soils. However, the smoke and haze resulting from the fires causes health risks for local populations. Air pollution is increasing through wildfires as plantations disturb climate regulation by changing microclimates, which make fires more prevalent.

Palm oil used for biofuel in the EU requires certification to meet REDII criteria. EC-recognised schemes, such as the International Sustainability & Carbon Certification (ISCC) EU scheme, are widely used for plam oil. ISCC EU includes criteria for 'good agricultural practice' and the establishment of a soil management plan.[170] This includes monitoring of soil organic carbon (SOC) and tracking nutrient inputs and outputs. The use of herbicides and mineral fertilizers is also permitted.[170]

Sustainable agronomic practices can mitigate negative soil impacts, close yield gaps, and provide income resilience to smallholder farmers. Young palm oil plantations (up to three years old) are especially vulnerable to erosion and other environmental impacts. If other plants are intercropped between the palms trees, it can increase the resilience of the plantation, reduce erosion, and serve as alternative income for smallholder farmers.[171] Additionally, organic matter from pruning, empty fruit bunches, waste biomass from processing, palm oil shells, and more can be returned to the soil to increase soil organic matter content and close nutrient cycles. The burning of biomass should be avoided for the same reasons. Ground cover with beneficial native plants and mosses should be fostered to prevent erosion rather than removed with herbicides. Additionally, weeds should be removed through mechanical practices rather than chemical management.[171]

Air Quality

Air quality is negatively affected by palm oil cultivation in Indonesia and Malaysia mainly through fires and erosion.[172] Land clearing for the establishment of new plantations is often done through burning of existing forests and peatland vegetation. For instance, in Katapang,

168 Moreno-Peñaranda, R., Gasparatos, A., Stromberg, P., Suwa, A., Puppim de Oliveira, J.A. Stakeholder Perceptions of the Ecosystem Services and Human Well-Being Impacts of Palm Oil Biofuels in Indonesia and Malaysia. (2018). https://doi.org/10.1007/978-4-431-54895-9_10.

169 Mohd Hanafiah, K., Abd Mutalib, A.H., Miard, P. et al. Impact of Malaysian palm oil on sustainable development goals: co-benefits and trade-offs across mitigation strategies. (2022). https://doi.org/10.1007/s11625-021-01052-4.

170 ISSC. (2022). ISSC EU 202-2 Agricultural Biomass: ISCC Principles 2-6. https://www.iscc-system.org/c.

171 Slingerland, M. A., et al. Improving smallholder inclusivity through integrating oil palm with crops. (2019). https://library.wur.nl/.

172 Meijaard, E., Brooks, T.M., Carlson, K.M. et al. The environmental impacts of palm oil in context. (2020). https://doi.org/10.1038/s41477-020-00813-w.

Indonesia, 90% of deforestation was a result of burning between 1989 and 2008.[173] The RED does not permit land use change for biofuel production, with a cut-off date of 2008. Additionally, 20% of all wildfires in Indonesia can be directly attributed to palm oil plantations.[174]

The current and past land-use change has led to altered ecosystems as the change in vegetation constellation has altered microclimates. For instance, the average temperatures on oil palm plantations are higher than in primary forests and drained peatlands[175] are especially vulnerable to fires.[168,169] Water cycling is also disturbed and plantations often have lower humidity levels and contain drier biomass, especially after draining peat. The altered microclimate and unsustainable agricultural practices also increase erosion risk. Eroded soils have lower water holding capacities, which, in turn, leads to drier environments that are at higher fire risk. Deforestation and peat drainage, together with increased heat periods due to climate change, increase the likelihood and severity of forest fires. The haze resulting from planned and unplanned forest fires has detrimental impact on human and wildlife health. Please note that this higher risk of fire and haze is present for all combinations of deforestation and peat drainage, not necessarily areas linked to palm oil plantations.

Additionally, during palm oil processing stages, untreated POME residues can release large quantities of methane, which contributes to air pollution and causes major greenhouse gas emissions.[168] Instead, residues can be treated and composted and used as biofertilizers to avoid pollution.

Sustainable palm oil farming practices, as described in the soil and biodiversity section, that avoid erosion and increase soil coverage and health help to mitigate negative effects on air quality and reduce destruction caused by wildfires.

Biodiversity

It has been estimated that oil palm expansion could affect 54% of threatened mammals and 64% of threatened birds globally.[176] 84% of all palm oil stems from Indonesia and Malaysia.[177] These tropical areas are very suitable for oil palm plantations, but also have a high biodiversity richness. Biodiversity loss is largely driven by ongoing habitat destruction due to land-use change related to palm plantations. Furthermore, existing plantations offer little resources for wildlife to co-exist. In Malaysia, 77% of agricultural land is used for oil palm, accounting for 15% of the total land area. Additonally, in Indonesia, researchers have estimated that one third of old growth forests were lost due to the palm oil industry alone.[178]

The Indonesian government acted in 2011 by introducing a national moratorium on developing oil palm plantations in areas of primary forests. This led to 137 palm oil companies losing their permits in 2022 and as a result, palm oil-driven deforestation has been the lowest in 20 years.[174] However, the area used for oil palm plantations has still doubled from 2011 to 2019 leading to potentially 11% forest decline, mainly driven by industrial scale plantations rather than smallholder farming.[179] Industrial oil palm plantations are characterized as large-scale operations under intensive agricultural management, which are owned by companies. In contrast, smallholder plantations occupy smaller areas and form a mosaic landscape and are often more diverse by incorporating two to three additional crops.[Error! Bookmark not defined.] However, because yields in small-holder operations are lower, their practices require more land if scaled.

173 ICCT. Ecological impacts of palm oil expansion in Indonesia. https://theicct.org.
174 ICCT. Ecological impacts of palm oil expansion in Indonesia. https://theicct.org.
175 The REDII does not permit biofuels stemming from land use change areas converted after 2008, however drained peatland converted before the cut-off date still poses a higher wildfire risk.
176 IUCN. (2018). Palm Oil and Biodiversity. https://www.iucn.org/.
177 Our World in Data. (2022). Palm Oil. https://ourworldindata.org/.
178 WUR, Indonesian deforestation and palm oil plantation expansion slows down. (2022). https://www.wur.nl/.
179 Gaveau DLA, Locatelli B, Salim MA, Husnayaen, Manurung T, Descals A, et al. (2022). Slowing deforestation in Indonesia follows declining oil palm expansion and lower oil prices.- https://doi.org/10.1371/journal.pone.0266178.

As oil palm is a high-yielding crop, diversion to other oil crops is likely less efficient as it may cause additional land-use change in other regions. Instead, unsustainable management practices should be replaced to stabilize future yield levels.[174] Biodiversity loss threatens oil palm plantation productivity as ecosystem services, such as pollination and biological control, are negatively affected. Sustainable Palm Oil certifications, such as the Roundtable on Sustainable Palm Oil (RSPO), the ISCC, and the Malaysia Sustainable Palm Oil (MSPO), are increasingly driving efforts to change the sector. In Malaysia, 63% of growers are certified by the MSPO and globally, 19% of palm oil is RSPO certified.[180] The sustainabiity criteria set in the REDII will require certification, which have been approved by the Commision. Currently this only includes the ISCC EU scheme, as previously mentioned.[181]

The sustainability criteria set out by the REDII and the ISCC EU scheme include exemplary practices that protect and restore biodiversity. They include connectivity of biomes through wildlife corridors and connected waterways, planting buffer zones around crucial areas, and developing measures to mitigate human-wildlife conflicts.[182] Mulching, cover cropping, and intercropping benefit production, protect biodiversity, and safeguard ecosystem services, such as water management and soil health.

Soy

Soybean is one of the dominant crops used for imported biodiesel to the EU. 40% of soy feedstock for biodiesel consumed in the EU stems from Brazil and 18% from Argentina, which are the first and third largest soy-producing countries in the world. Furthermore, 21% of soy feedstock used for biodiesel consumed in the EU originates from the USA, the second largest soy producer globally.

The demand for soybean oil for biofuel in Brazil has been drastically increasing. Since 2010, the demand of soybean oil for biodiesel production has more than doubled in Brazil, making it one of the largest biodiesel producers in the world.[183] On the other hand, in Argentina, the consumption of soybean oil for biodiesel production has dropped significantly since 2019.[184] In 2021, Argentina produced approximately 1.54 billion litres of biodiesel,[185] roughly a quarter of Brazil's production.[186] However, Brazil consumes a large share of biodiesel internally; therefore, Argentina remains the largest exporter of soybean oil products.[185][186][187] The USA produced approximately 3.4 billion litres of soybean oil for biofuels in 2022, of which 10% were exported.[188]

The recent COVID-19 pandemic and the war in Ukraine have increased global demand and commodity prices driving further expansion of soy for animal feed and biodiesel production in South America and the USA.[189] In fact, researchers estimate that Brazil alone will convert 23 million hectares to soybean production in the next 15 years, where around a fourth of the expansion is expected to occur in rainforest and savannah areas.[190] While many studies have concluded that the direct driver of land conversion in South America is cattle farming, this neglects the indirect impact of soy cropland expansion.[192] After conversion, land is initally used as pasture for cattle and then converted to cropland for soy production.

180 Dutch Minsitry of Foreign Affairs. (2023). Sustainability in the palm oil sector. https://www.netherlandsandyou.nl/.
181 European Commission. (2023). Voluntary Schemes. https://energy.ec.europa.eu/.
182 RSPO. (2020). Palm Oil grown for good: protecting our ecosystems and wildlife, and how consumers can contribute. https://rspo.org/p.
183 Statista. (2023). Volume of soybean oil used in biodiesel production in Brazil from 2009 to 2021. https://www.statista.com/statistics.
184 Statista. (2023). Soybean oil used in biodiesel production in Argentina from 2010 to 2021 https://www.statista.com/.
185 USDA, Foreign Agricultural Service. (2023). Argentina: Biofuels Annual. https://www.fas.usda.gov.
186 USDA, Foreign Agricultural Service. (2023). Brazil: Biofuels Annual. https://www.fas.usda.gov.
187 Colussi, J., N. Paulson, G. Schnitkey, and S. Cabrini. (2023). Record in Brazil, Drop in Argentina: Contrasting Soybean Harvests in South America. https://farmdocdaily.illinois.edu/.
188 USDA. (2023). Examining Record Soybean Oil Prices in 2021–22. https://www.ers.usda.gov.
189 Marin, F.R., Zanon, A.J., Monzon, J.P. et al. (2022). Protecting the Amazon forest and reducing global warming via agricultural intensification. https://doi.org/10.1038/s41893-022-00968-8.
190 Marin, F.R., Zanon, A.J., Monzon, J.P. et al. (2022). Protecting the Amazon forest and reducing global warming via agricultural intensification. https://doi.org/10.1038/s41893-022-00968-8.

Globally, 20% of produced soy is used for direct human consumption, 76% is used for animal feed, 2.8% is used for biodiesel, and the remaining for other industrial uses. Demand for soy for direct human consumption and unprocessed animal feed has remained relatively stagnant in the past 20 years, meaning soy demand has largely been driven by processed soy products, which include processed feed, biofuels, and vegetable oil.[191] As soy demand continues to increase, so does the demand for cropland, since yield gains can not fill the gap.[191] As a result, soy farming can displace pasture, which causes further land-use change of natural ecosystems.[192] Avoiding expansion into fragile and biodiverse ecosystems creates vast economic opportunity costs (over 400 billion USD for Brazil alone) and can reduce potential social benefits of soy farming such as increased income, nutrition, and living standards,[193] although positive social impacts of intense soy production have also been disputed.[194]

The Great Plains are one of the most ecologically significant ecosystems in the USA. They cover 2.9 million square kilometers, roughly a third of the country. However, less than 2% of their area are currently under protection in natural reserves.[195] Beginning in the 1950s, the Great Plains have been increasingly and rapidly converted, and now make up 25% of the total USA cropland.[196] They are still the area with the highest land use conversion rate in the USA.[197]

The EU regulation on deforestation-free products, which was agreed in 2023, will require traders importing soy to the EU for any end-use purposes to prove "that the products do not originate from recently deforested land or have contributed to forest degradation".[198] The aim of the regulation is to reduce greenhouse gas emissions, in line with the REDII, and limit biodiversity loss. Soy-derived biofuel imports, therefore, must comply with the deforestation regulation and additional requirements as laid out by the REDII, which has a broader scope of exclusion including peatlands, wetlands, and biodiverse grasslands.[187]

Overall, limited area expansion and increased demand for soy commodities has promoted agricultural intensification, more recently in Argentina and Brazil, and continuously in the USA.[199,200] Studies have shown that agricultural intensification due to soy production negatively affect the provision of ecosystem services. For instance, it has led to negative impacts on water quality, reduced soil fertility, increased erosion, and reduced pollination.[201]

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

191 Hannah Ritchie and Max Roser. (2021). Forests and Deforestation. https://ourworldindata.org/.
192 Elizabeth Barona et al. (2010). The role of pasture and soybean in deforestation of the Brazilian Amazon. https://doi.org/10.1088/1748-9326/5/2/024002.
193 Dreoni, Ilda. Schaafsma, Marije. Matthews, Zoe. (2021). The Social Impacts of Soy Production: A Systematic Review. https://tradehub.earth/.
194 Gabriela Russo Lopes, Mairon G. Bastos Lima, Tiago N.P. dos Reis. (2021). Maldevelopment revisited: Inclusiveness and social impacts of soy expansion over Brazil's Cerrado in Matopiba. https://doi.org/10.1016/j.worlddev.2020.105316.
195 WWF. (2023). Disappearing grasslands. https://wwf.panda.org/.
196 USDA. (2023). Focus on Croplands in the Northern Plains. https://www.climatehubs.usda.gov/.
197 Lark, T.J., Spawn, S.A., Bougie, M. et al. (2020). Cropland expansion in the United States produces marginal yields at high costs to wildlife. https://doi.org/10.1038/s41467-020-18045-z.
198 European Commission. (2023). Deforestation-free products. https://environment.ec.europa.eu/.
199 Tomei and Upham. (2009). Argentinean soy-based biodiesel: An Introduction to production and impacts. Energy Policy. https://doi.org/10.1016/j.enpol.2009.05.031.
200 Rafael De Oliveira Silva, Luis Gustavo Barioni, Giampaolo Queiroz Pellegrino, Dominic Moran. (2018). The role of agricultural intensification in Brazil's Nationally Determined Contribution on emissions mitigation. https://doi.org/10.1016/j.agsy.2018.01.003.
201 Dreoni, Ilda. Schaafsma, Marije. Matthews, Zoe. (2022). The impacts of soy production on multi-dimensional well-being and ecosystem services: A systematic review. https://doi.org/10.1016/j.jclepro.2021.130182.

Water quality

In Brazil and Argentina, agricultural intensification and crop expansion is driven by soy and corn[202], which results in direct pollution of water sources and also negatively impacts the ecosystems services that provide clean water, such as soil filtration.[201]

Agrochemicals, such as pesticides, herbicides, and synthetic fertilizers, are used in intense crop production to increase yields and limit manual labour. However, many of these chemicals enter water bodies through diffusion, dispersion, and permeation, which pollute drinking water sources, harm wildlife and laborers, and disrupt the aquatic environment.[203] A recent study analyzing drinking water contamination in agricultural areas in Brazil found a high correlation for pesticide-induced cancers.[204] Another study found that 97% of municipalities in grain-producing regions had pesticide levels significantly above the EU-recommended limits in their drinking water supply.[200]

Fertilization leads to nitrate and phosphorus leaching, which can cause eutrophication and disrupt ecosystems by overstimulating algal, plant, and bacterial growth. Ultimately, this can create dead zones in water bodies by robbing oxygen necessary to support most organisms. For instance, in Lajeado Reservoir in Brazil, agricultural activities increased the concentration of nutrients and pesticides so that over 90% of the surface area was covered by plants, causing high ecological risk and incurring high costs since the plants to be needed to be removed manually.[205]

Additionally, water availability is threatening soy production as climate change is increasing the frequency and length of droughts. In Argentina, a massive drought is threatening soy yields; the projected harvest for 2023 is 40% lower than in 2022, which would be the lowest harvest in the past 20 years.

Soil quality

Soybeans have relatively low oil content, producing on average 500 liters of oil per hectare, therefore, biofuel production based on soy requires large areas of land. In 2021, there were approximately 16 million hectares under soy production in Argentina and 39 million hectares under soy production in Brazil.[206] Agricultural expansion is the main driver of deforestation, however, import of soy products from deforested areas is limited under EU regulation to areas which were deforested before 2021. By 2018, 2.2 million hectares had been deforested due to soy production, with Matopiba as one of the highest risk regions, which is part of the Cerrado biome in Brazil.[207] In Argentina, the Chaco region experienced the largest deforestation with more than 1 million hectares lost between 2010 and 2018.[203]

Biodiversity and soil fertility are threatened by agricultural expansion. Intensive agricultural practices rely on mechanical soil management, such as tillage and ploughing, as well as the use of agrochemicals to improve yields. These practices often lead to reduced soil fertility and increased erosion in the long term as they alter soil structure and aggregates.[201] Soils are unable to retain and drain water well and rooting is poor, resulting in yield penalties in the longer term. Vast monocultures and non-diverse cropping rotations drive erosion risk and disease pressure, which can harm crop yields and increase pesticide use. These practices also reduce SOC, which prevents soil GHG emissions and supports ecosystem

202 Damien Arvor, Margareth Meirelles, Vincent Dubreuil, Agnès Bégué, Yosio E. Shimabukuro. (2012). Analyzing the agricultural transition in Mato Grosso, Brazil, using satellite-derived indices. https://doi.org/10.1016/j.apgeog.2011.08.007.
203 Rad, Samira Mosalaei, Ajay K. Ray, and Shahzad Barghi. (2022). Water Pollution and Agriculture Pesticide. https://doi.org/10.3390/cleantechnol4040066.
204 Carolina Panis, Luciano Zanetti Pessôa Candiotto, Shaiane Carla Gaboardi, Susie Gurzenda, Jurandir Cruz, Marcia Castro, Bernardo Lemos, (2022). Widespread pesticide contamination of drinking water and impact on cancer risk in Brazil. https://doi.org/10.1016/j.envint.2022.107321.
205 Ogura AP, Pinto TJDS, da Silva LCM, Sella CF, Ferreira FBC, de Carvalho PS, de Menezes-Oliveira VB, Montagner CC, Osório AL, Espíndola ELG. (2022). Environmental analysis of the eutrophication and spread of aquatic macrophytes in a tropical reservoir: a case study in Brazil. https://doi.org/10.1007/s11356-022-22070-4.
206 Food and Agriculture Organization of the United Nations. FAOSTAT Statistical Database.
207 Trase. (2023). Trase Insights: The state of forest risk supply chains. https://insights.trase.earth.

services such as water filtration, soil structural stability, microbial activity, and nutrient cycling and availability.

In Brazil, Argentina, and the USA, soy is commonly planted in short crop rotations with maize because the crops are complimentary and result in high-yielding rotations. However, soy and maize rotations are low in diversity and require relatively high amounts of fertilizer and pesticide input in intensive systems.[204] For instance, studies have shown that nitrogen-fixing abilities of soy are not utlized as the plant draws most nitrogen from the soil in rotations with maize.[208]

Sustainable intensification is a process where agricultural yields are increased without negative environmental impact and without land-use change and deforestation.[209] Models have demonstrated that the average soy yield gap is up to 35% in the Amazon and Cerrado regions of Brazil[190] and 17% in Argentina.[210] Closing these yield gaps and avoiding further land-use change can support countries meeting their emission reduction targets as set in their Natioanlly Determined Contributions (NDCs), support further economic development, and preserve vital ecosystems.

Air Quality

Land clearing is often done by burning down forested area, which causes a rise in fine particulate matter. The increase in fine particulate matter causes disease and even premature deaths for local population, leads to yield losses, and results in environmental damage. Annual crop losses could rise to 9 million tons by 2050 for staple crops, including soybean.[211] Desertification driven by past and present land conversion, as well as increased erosion due to intensive agricultural practices are increasing the prevalence of dust storms and other dust events. Dust storms damage crops and carry away fertile topsoil, which impacts agricultural productivity.[212]

Droughts dry out the soil, which increase the likelihood of dust storms. In 2010, Argentina experienced a dust storm following a severe drought period. The storm caused severe damage and yield losses. Argentina has experienced a severe drought period in the current cropping season and is expecting the lowest production in the past 20 years, which may be further exacerbated by dust storms in the following seasons.[213] In the Great Plains in the USA, there is growing concern of dust storms increasingly occurring and potentially reaching levels of the Dust Bowl storms in the 1930s, which had devastating effects on farming and caused millions to migrate.[214] In particular, recent agricultural expansion for crop biofuel production has been identified as strongly correlating with areas where dust levels are growing rapidly.[210]

The agricultural sector can reduce its impact by limiting agricultural expansion, stopping open-field agricultural burning, and reducing methane emissions by utilizing biogas for plant material recycling and implementing practices that reduce soil disturbance, including limiting ploughing and increasing soil coverage and stability. Soy grown for biofuel consumption in the EU already reduces negative impacts by requiring sustainabiity criteria to be met and thus, may act as starting point for sustanable practices to be implimented beyond crops destined for biofuel production.

208 Neupane, A., Bulbul, I., Wang, Z. et al. (2021). Long term crop rotation effect on subsequent soybean yield explained by soil and root-associated microbiomes and soil health indicators. https://doi.org/10.1038/s41598-021-88784-6.
209 Jules Pretty, Zareen Pervez Bharucha. (2014). Sustainable intensification in agricultural systems, Annals of Botany. https://doi.org/10.1093/aob/mcu205.
210 Cecilia Crespo, Leonardo Novelli, Nicolás Wyngaard, Roberto Dionisio Martínez, Mirian Barraco, Vicente Gudelj, Pedro Barbagelata, Pablo Andrés Barbieri. (2023). Optimizing resource productivity in soybean-based sequences through long-term crop intensification, Field Crops Research. https://doi.org/10.1016/j.fcr.2023.109018.
211 UNEP. (2023). Efforts to reduce air and climate pollutants in Latin America could reap immediate health benefits. https://www.unep.org/.
212 UNEP. (2023). Sand and dust storms. https://wedocs.unep.org/.
213 Colussi, J., N. Paulson, G. Schnitkey, and S. Cabrini. (2023). “Record in Brazil, Drop in Argentina: Contrasting Soybean Harvests in South America. https://farmdocdaily.illinois.edu/.
214 Pease, R. (2020). Rising Great Plains dust levels stir concerns. doi:10.1126/science.abf3504.

Biodiversity

Agriculture is the main driver of biodiversity loss and has been estimated to threat 86% of species that are at risk of extinction.[215] The current and past expansion of farmland in Argentina, Brazil, and the USA has caused severe biodiversity loss driven by habitat loss. However, even post land-use change intensive agricultural practices drive further biodiversity loss on the field, farm, and landscape scale. Some of these effects have already been discussed in the previous water, soil, and air quality sections. Biodiversity loss is directly linked to agricultural intensity. For instance, a study found that by doubling cereal yields, such as soy, half of the plant species and about one third of the ground beetle and bird species – all indicators for biodiversity impact – were lost.[216] Furthermore, practices attributed to intensive agriculture including insecticide, herbicide, pesticide, and fungicide use, as well as large monoculture areas, critically endanger biodiversity and are commonly used for typical production export crops, including soy.[217] These practices are driving biodiversity loss in South America. On the other hand, functional biodiversity is critical to agricultural production and to maintaining required ecosystem services, such as pollination and biological pest control. Hence, biodiversity loss reduces yield quality and quantity.[218]

More extensive agricultural systems have less impact on biodiversity but require more area as production levels per hectare are lower. In Argentina, Brazil, and the USA, agricultural expansion is currently the main threat to biodiversity; hence, sourcing has been limited for EU imports under REDII requirements. Sustainable intensification can protect biodiversity by lowering the demand for agricultural expansion, reducing the impact of agricultural practices on the environment, and maintaining or increasing production levels.

4.2.3. Potential future developments

The decarbonization of industry will drive demand for biomass. If more biomass is produced, it will increase land pressure as biomass crop production competes with food crop production feeding a growing global population. As a result, the EU has put legislation in place, including the REDII, to steer agricultural production, ensure food security, enhance land use and foster sustainable development in the sector.

The sustainability certifications that have been introduced by the REDII, especially the schemes with additional environmental requirements, have laid the foundation to drive sustainable farming practices and can have an effect beyond biofuel feedstock production.

Integration of biofuel feedstock and food production can foster sustainable practices. Furthermore, the concept of low ILUC-risk biofuels has been introduced in the REDII, which focuses on producing “additional biomass” through additional yields or new crop production on unused, abandoned or severely degraded land to avoid competition with food production. For example, biofuel feedstock production can provide financial incentives that make cover, strip- and intercropping with food crops more attractive to farmers and positively benefit soil health and biodiversity. Another example is the use the use of Brassica carinata as a sequential crop (planted in between two main crops in a crop rotation) in Uruguay. The plant provides additional benefits to farmers as it can be planted in Winter, outside of the main agricultural season, to protect soils from erosion and generate additional income. Alternatively, biofuel feedstock production can incentivize the regeneration of degraded lands to counter desertification, especially if for instance, if a premium is developed to incentivize investment in less productive areas.

215 UNEP. (2023). Our global food system is the primary driver of biodiversity loss. https://www.unep.org/.
216 Geiger, F., Bengtsson, J., Berendse, F., et al. (2010). Persistent negative effects of pesticides on biodiversity and biological control potential on European farmland. doi:10.1016/j.baae.2009.12.001.
217 Peter H. Raven and David L. Wagner. (2021). Agricultural intensification and climate change are rapidly decreasing insect biodiversity. https://doi.org/10.1073/pnas.2002548117.
218 Schütte et al. (2017). Herbicide resistance and biodiversity: agronomic and environmental aspects of genetically modified herbicide-resistant plants. Environ Sci Eur 29, 5.

Environmental issues that have been addressed by biofuel policies have led to support for different initiatives in agriculture. One example where this has already occurred for upcoming legislation is the European Commission proposal for the Soil Monitoring Law. The proposal focuses on specifying conditions for healthy soils, soil monitoring and rules for sustainable soil use and restoration within the EU. Another soon-to-be implemented legislation prohibits the use of soy, palm oil, and some other commodities if they are produced on land that was deforested. This is similar to biofuel policies ruling out that direct land-use change has occurred in the production of that crop or commodity.

Lastly, the development of advanced biofuels promotes the technological development of conversion technologies and makes them available sooner. This allows more biomass wastes and residues to become available and be used for material purposes and reduces the pressure on land use as crop residues and other waste biomass can be utilized, unlocking further potential.

4.3. Source and impact on LULUCF sink

MSs are required to report on how biofuels, bioliquids, and biomass fuels produced from biomass meet land-use, land-use change, and forestry (LULUCF) criteria, as stated in Article 29(7) of Directive (EU) 2018/2001. The LULUCF sector encompasses emissions and removals mainly from forests, but also from croplands, grasslands, wetlands, and others.[219] For the NECPRs, MSs were requested to provide information specifically on forest biomass.

The aim of this section is to provide an overview and qualitative analysis of the information on LULUCF specified by MSs in their NECPR reporting, allowing for aggregation on the European level and comparisons between MSs. The overview and analysis are specifically for forest biomass and its source and impact on LULUCF sinks, and thus excludes agricultural carbon sinks and stocks.

Background on the EU LULUCF sector

At the EU level, the LULUCF sector serves the purpose of being a CO_2 sink, offsetting around 7% of GHG emissions from other high polluting sectors[220]. A forest carbon sink refers to when the uptake or removal of carbon from the atmosphere exceeds the total amount of carbon released.[221] On the other hand, forests are considered a carbon source when total emissions exceed total carbon removal.[222] Emissions of carbon are determined by natural disturbances such as fires, storms, floods, and harvesting.

Regarding carbon dioxide removals from biomass, the EU-27 has seen the number of removals decrease from 2010 to 2020. Additionally, carbon stock has decreased in 2020 compared to 2015 (from 9,983 to 9,552 Mt carbon stock).[223] However, when comparing 2020 to 1990, the annual change in carbon stock in the EU-27 has increased (from 6,600 to 9,552 Mt carbon stock). Given its importance for climate change mitigation, the LULUCF sector was included in the 2030 climate targets under the Paris Agreement, with the specific target of reducing GHG emissions by 40% in 2030 relative to 1990.[224]

219 European Commission. LULUCF. Forest (europa.eu).
220 European Commission, LULUCF. Forest (europa.eu).
221 Forest Information System for Europe, Carbon Sinks and Sources. Carbon Sinks and Sources (europa.eu).
222 Forest Information System for Europe, Carbon Sinks and Sources. Carbon Sinks and Sources (europa.eu).
223 Forest Information System for Europe, Carbon Sinks and Sources. Carbon Sinks and Sources (europa.eu).
224 European Commission, LULUCF. Forest (europa.eu).

Overview MS reports

At the time of writing, only 18[225] MSs reported any information on LULUCF in Annex II. Out of the MSs that submitted NECPRs, the following did not report information on LULUCF: Greece, Italy, and Slovakia. This section provides an aggregated overview of the information provided by the 18 MSs. In the table below, additional information beyond the overview is displayed for selected MSs based on information provided in the NECPRs.

MSs provided limited information on LULUCF and reported mainly on three aspects: 1) being a signatory of the Paris Agreement, 2) having submitted the NDC to the United Nations Framwork Convention on Climate Change (UNFCCC), and 3) having implemented national or sub-national laws applicable to the LULUCF sector to ensure that emissions do not exceed removals.

Firstly, all MSs that reported information are signatories of the Paris Agreement, and thus, are in compliance with this specific criteria in Article 29(7) of Directive (EU) 2018/2001.

Secondly, eight[226] out the 18 MSs explicitly indicated in their NECPR that they have submitted an NDC to the UNFCCC. However, the UNFCCC database[227] shows that the remaining 10[228] MSs have also submitted NDCs, which have active statuses. Hence, all 18 MSs that have reported information on LULUFC fulfil this specific criteria of Article 29(7) Directive (EU) 2018/2001.

In relation to the implementation of national or sub-national laws, 13[229] out of the 18 MSs that provided NECPRs explicitely state that laws related to Article 29(7) Directive (EU) 2018/2001 have been established. Due to the limited information provided, it is unknown whether the remaining MSs have implemented national or sub-national laws.

Table 19: Information provided in MS Progress Reports to Annex II, table 6. Source: MS Progress Reports

Member State	Information reported on LULUCF
Bulgaria	The MS reports it has implemented the Directive (EU) 2018/2001 requirement in an amendment to their Energy from Renewable Sources Act, to be adopted by the National Assembly after its formation.
Croatia	The MS states that it reports GHG emissions that include the LULUCF sector under the Kyoto Protocol, which has been mandatory since 2008. At the national level, legal acts regulate forest harvesting intensity, and enhancement of carbon stocks and removals by sinks by ensuring emissions do not exceed removals.
Cyprus	The MS reports that the forest biomass used for energy purposes is negligible.
Czechia	The MS reports it has implemented national legislation imposing new requirements related to the production and energy use of biomass, and regarding the documentation on biomass supplies throughout the supply chain and related GHG savings (Act no 382/2021). Operators of biogas stations or electricity plants and heating plants burning wood chips or straw must meet similar requirements as producers of biofuels.
Finland	The MS reports that LULUCF criteria for forest biomass were nationally transposed in 2021. All economic actors with a national sustainability scheme must provide information on the origin of forest biomass and evidence to comply with the criteria. All approved countries and forest sourcing areas are listed in sustainability schemes of each economic actor.
France	The MS reports that in the NDC to the UNFCCC, France covers emissions from agriculture, forestry, and land use, ensuring that changes in carbon stock associated with biomass harvesting are considered for the purpose of the commitment to reduce GHG emissions.
Latvia	The MS reports that the sustainability criteria are fulfilled for EU ETS operators, and that it also fulfils criteria set in Article 29(6) and 29(7) of REDII.

225 Austria, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Hungary, Latvia, Lithuania, Malta, Netherlands, Portugal, Slovenia, Spain, and Sweden.
226 Austria, Croatia, Estonia, France, Hungary, Portugal, Slovenia, and Sweden.
227 Nationally Determined Contributions Registry | UNFCCC.
228 Bulgaria, Cyprus, Czechia, Denmark, Finland, Latvia, Lithuania, Malta, Netherlands, and Spain.
229 Austria, Bulgaria, Croatia, Czechia, Denmark, Estonia, Finland, Lithuania, Netherlands, Portugal, Slovenia, Spain, and Sweden.

Lithuania	The MS reports that, in 2022, biofuel purchased on the national market used by operators participating in the EU emission allowance system is considered to meet biomass sustainability indicators including LULUCF criteria.
Malta	The MS reports that solid biomass is used solely in the residential sector with all installations with capacity lower than 20MW.
Portugal	The MS reports that it meets the accounting requirements for the LULUCF sector. For the period 2021-2030, this requirement has been elaborated in its national plan for forestry accounting ("Plano de Contabilidade Florestal Nacional para of sub-periodo 2021-2025"). The MS also provided a report on accounting available in the European Environment Agency Central Data Repository.[230]
Slovenia	The MS reports that national and sub-national laws include rules on felling, wood residues management, harvesting and stacking of timber assortments, and rules on forest management plans and game management plans.

Additional insights for some MSs

In Forest Information System for Europe[231], additional data is provided on LULUCF for eight[232] of the MSs that reported on the topic within the NECPRs. There are two major trends that can be observed with the additional source indicated. Firstly, as shown in the table below, there is an increase in forest carbon stock for seven out of the eight countries from the years 1990 to 2020. This is relevant because carbon stock represents the amount of sequestered carbon from the atmosphere, which is then stored in the forest ecosystem.[233] Portugal is the only MS excluded from this list of countries, as there is no data available for the years 1990 and 2000. This trend reflects data on a broader European level, as the annual change in carbon stock for the EU-27 has also increased from 1990 to 2020.

Table 20: Forest carbon stocks (Mt) per MS (1990 - 2020)

Member State	Forest carbon stocks (Mt)			
	1990	2000	2010	2020
Bulgaria	70	90	101	115
Croatia	99	99	98	101
Estonia	216	220	223	225
Hungary	60	63	64	70
Lithuania	170	173	174	182
Netherlands	67	73	80	83
Portugal	-	-	27	27
Slovenia	207	225	231	265

The second trend that can be observed is the decrease in GHG emissions for the LULUCF sector in 2020 compared to 1990 for all eight countries. However, for five[234] out the eight countries, there is an increase in GHG emissions in 2010 compared to 2000, followed by a decrease in 2020. The Netherlands and Hungary, however, see a decrease per decade from 1990 to 2020. Portugal also differs from the other countries, as it sees an increase in emissions in both 2000 and 2010, followed by a decrease in 2020 compared to 1990 levels.

230 European Environment Agency, Central Data Repository. MMR Template IRArticle 23_2019_PT.
231 Forest Information System for Europe. Climate reporting (europa.eu).
232 There is information available for eight out of the 18 MSs that reported on LULUCF in the NECPRs: Bulgaria, Croatia, Estonia, Hungary, Lithuania, Netherlands, Portugal, and Slovenia.
233 Forest Research. Tools and Resources, Forest carbon stock. Forest carbon stock - Forest Research.
234 Bulgaria, Croatia, Estonia, Lithuania, and Slovenia.

Table 21: GHG emissions (Mt CO_2e) per MS (1990 - 2020)

Member State	GHG emissions (Mt CO_2e)			
	1990	2000	2010	2020
Bulgaria	99	58	60	48
Croatia	32	26	28	24
Estonia	40	18	21	11
Hungary	95	75	67	63
Lithuania	48	20	21	20
Netherlands	223	220	215	165
Portugal	60	83	70	58
Slovenia	19	19	20	16

4.4. Impact of increased demand for biomass on biomass using sectors

It must be noted that no explicit reporting was done on biomass demand per feedstock type, only on the bioenergy demand per type within transport, electricity generation, and heating and cooling. As information on biomass demand is not currently included in the reporting obligations in the NECPRs, these could be expanded in the future to include biomass demand. The current data available does not facilitate an insight into what exact feedstocks are in demand, making a comparison with information from literature difficult.

4.5. Availability and resource competition Annex IX feedstocks

In this section, we discuss the EU-27 use, supply, and future supply potential of all Annex IX A feedstocks based on an analysis of available literature. The residual and very broad categories of p) and q) are not discussed, as these could include anything from energy crops to waste streams and are therefore difficult to describe, quantify, and assess other uses for. Quantitative supply and future potential data are included where relevant information was found in literature, but this was not the case for all Annex IX feedstocks. An overview of the amounts of Annex IX biofuels used in transport per feedstock type are provided in Table 22.

Table 22: Trends of use biofuels and biogas in transport produced from Annex IX. Source: Eurostat SHARES database

Annex IX feedstock	Use of biogas and biofuels produced from feedstock in transport [ktoe]					
	2016	*2017*	*2018*	*2019*	*2020*	*2021*
(a)	0	0	0	0	0	0
(b)	0	4	17	32	40	44
(c)	21	24	24	61	94	137
(d)	460	385	292	417	510	800
(e)	0	0	0	0	5	9
(f)	33	44	66	64	85	104
(g)	3	5	49	213	285	695
(h)	0	0	1	1	124	10
(i)	1	2	1	9	8	27

Annex IX feedstock	Use of biogas and biofuels produced from feedstock in transport [ktoe]					
	2016	*2017*	*2018*	*2019*	*2020*	*2021*
(j)	0	0	0	1	3	8
(k)	17	19	21	39	32	38
(l)	0	0	0	0	1	1
(m)	0	0	0	0	0	0
(n)	0	0	0	0	0	0
(o)	52	127	124	134	34	224
(p)	1	0	1	3	2	5
(q)	1	0	1	0	0	0
Part B						
(a)	1,074	1,354	1,803	2,288	2,527	2,580
(b)	379	352	518	505	534	793

Part A

a) Algae if cultivated on land in ponds or photobioreactors;

Algae are a category of plant-like organisms that grow at a high rate within a temperature range of 20°C - 30°C, for which they require sunlight, CO_2, water, and inorganic salts. Multicellular macroalgae can be cultivated on land in open ponds, whilst single cellular microalgae are grown in closed photobioreactors. The lipid fraction of algae can be used as feedstock for the production of biodiesel, whereas the carbohydrate fraction can be utilized for bioethanol or butanol production. Hydrogen and biogas could also potentially be produced from algae, although development is still in its early stages.[235] Non-fuel applications of algae include use as feedstock in the production of high value pharmaceuticals, cosmetics, chemicals, nutritional supplements (nutraceuticals), as well as use in animal feed, pigments, fertilizer, and waste water remediation. No algae-based biofuels are currently being produced across the EU-27 due to a limited level of technology readiness and high production costs.[236, 237] This means risk of resource competition is low. As algae are not a waste or by-product, there is no highest value retention option to be achieved within the waste hierarchy.

b) Biomass fraction of mixed municipal waste**, but not separated household** waste **subject to recycling targets under point** (a) **of Article** 11(2) **of Directive** 2008/98/EC**;**

This biomass fraction of mixed municipal (solid) waste (MSW) mainly includes paper, food waste, wood, textiles, and other inorganic wastes. It currently remains largely unutilized for biofuel production due to the lower level of technology readiness and cost-competitiveness with other biofuel production pathways.[238] Alternative uses include further recycling, electricity and heat generation at waste incineration plants, and landfilling. Further material recycling represents the highest option within the waste hierarchy. Therefore, recyclables should always first be removed to the extent that this is viable before other applications are

235 Sharma & Sharma. (2017). Industrial and Biotechnological Applications of Algae: A Review. Industrial and Biotechnological Applications of Algae: A Review - Open Access Pub (ijn-medicalarticles.info)
236 Eurostat SHARES database
237 IEA Bioenergy. (2017). State of Technology Review – Algae Bioenergy. IEA Bioenergy Algae report update - Final template 20170114-no trackchanges.
238 Kowalski et al. (2022). Second-generation biofuel production from the organic fraction of municipal solid waste. Frontiers | Second-generation biofuel production from the organic fraction of municipal solid waste (frontiersin.org).

pursued. As significant fractions of MSW are still being landfilled, resource competition for the biomass fraction is not a significant issue at this point in time.[239]

Total MSW generation in the EU-27 was 2,368,000 kilotons in 2021.[240] An estimated 30-40% of EU MSW consists of biomass, implying that the total biomass fraction of MSW generated is about 83,000 kilotons.[241] This represents the total theoretical potential; however, since significant amounts will be recycled or used for energy generation (according to the waste hierarchy outlined in the Waste Framework Directive (Directive Directive 2008/98/EC) the actual potential will be lower. The use of biofuel and biogas based on this feedstock was 44 ktoe in 2021 and has steadily grown since first being used in 2017, although the growth rate has somewhat stagnated.[236]

c) Biowaste as defined in point (4) **of Article** 3 **of Directive** 2008/98/EC **from private households subject to separate collection as defined in point** (11) **of Article** 3 **of that Directive;**

This feedstock includes biodegradable garden, park, food, and kitchen waste from various sources. Starting from the end of 2023, food waste must be collected separately from households. As with algae, its lipid fraction can be used to produce biodiesel and glycerine via chemical conversion, while its carbohydrate fraction can be converted to biogas via anaerobic digestion or to bioethanol via fermentation.[242] Pyrolysis or gasification are other pathways that, in theory, could be used to produce liquid and gaseous fuels from this feedstock. Composting is another potential application, and biogas can be produced from the composting residue.[243] Alternative applications are animal feed, donation (of leftover food), landfill, and energy recovery. Food waste generation should be prevented to the highest extent possible as it is a relevant cause for concern and its prevention could lead to significant environmental benefits, such as reduced land use and avoided methane emissions in landfills.[244] Prevention also represents the highest option within the waste hierarchy. As reusing biowaste is not possible and complete waste prevention is not feasible, recycling for the production of biofuels and/or biogas is the second-best way to retain value.

According to a 2020 report by Zero Waste Europe and the Bio-based Industries Consortium, the theoretical potential of biowaste generated by households in the EU-27 was 98,528 kilotons tons per year (113,817 kilotons for what the authors define as EU-27+, which includes the UK and Norway).[245] Of this total potential, 34% was, on average, collected across the EU-27+ (no percentage available for EU-27 only), which is around 38,698 kilotons when this percentage is applied to the EU-27 fraction of waste produced. The use of biofuel and biogas produced from Annex IX biowaste in transport across the EU-27 was 94 ktoe in 2020 and increased to 137 ktoe in 2021.[236] There, therefore, seems to be a difference in order of magnitude between the amount of feedstock collected and the amount of biofuel produced. Even though the increase in production over the last years has been significant, there seems to be leeway for future production increases since collection across

239 European Environment Agency. (2020). Bio-waste in Europe — turning challenges into opportunities. Bio-waste in Europe — turning challenges into opportunities — European Environment Agency (europa.eu).
240 EU-27: municipal waste generation | Statista.
241 Facts and figures, EU demographics | European Union (europa.eu).
242 Pour & Makkawi. (2021). A review of post-consumption food waste management and its potentials for biofuel production. A review of post-consumption food waste management and its potentials for biofuel production - ScienceDirect.
243 Singh et al. (2022). Food Waste Valorisation for Biogas-Based Bioenergy Production in Circular Bioeconomy: Opportunities, Challenges, and Future Developments. Frontiers | Food Waste Valorisation for Biogas-Based Bioenergy Production in Circular Bioeconomy: Opportunities, Challenges, and Future Developments (frontiersin.org).
244 Scherhaufer et al. (2018). Environmental impacts of food waste in Europe. Environmental impacts of food waste in Europe - ScienceDirect.
245 Zero Waste Europa and the Bio-based industries consortium. (2020). Bio-waste generation in the EU: Current capture levels and future potential Bio-waste generation in the EU: Current capture levels and future potential - Zero Waste Europe.

EU-27 is still relatively low, landfilling is still being done, and reports on resource competition were not found, which implies the degree of competition is low.

d) Biomass fraction of industrial waste **not fit for use in the food or feed chain, including material from retail and wholesale and the agro-food and fish and aquaculture industry, and excluding feedstocks listed in Part B of this** Annex**;**

This feedstock category consists of a wide range of waste streams including paper, cardboard, wood, and food processing residues. A list with relevant feedstocks included in this category can be found in Annex IV of the EC's Implementing Regulation 2022/996. Due to the breadth of this category, a lot of different biofuels can be produced from it depending on the exact feedstock composition. Agro-food and aquaculture wastes typically have a high moisture content. Therefore, they are best suited for anaerobic digestion when used for biofuel production, as the energy requirements for gasification-based technologies are too high. However, wastepaper and wood can be used for pyrolysis and Fischer-Tropsch synthesis.[246] Other uses of this feedstock include further recycling and application in value added plant cultivation (to construct irrigation systems or as fertilizer), construction materials, and in producing of sorbents for wastewater cleaning.[247] In the future, it could also potentially serve as raw material for the chemical industry.[248]

Out of all the Annex IX Part A feedstocks used for biofuels and biogas in transport, the biomass fraction of industrial waste has been used most by the EU-27 since 2016 with 800 ktoe of fuels used in 2021.[236] Although the total amount has fluctuated over the years, the use of this category of fuels has been on the rise since 2019. Unfortunately, no numbers on supply and potential of the biomass fraction of industrial waste were found in literature.

e) Straw;

Cereal straw

Traditionally, agricultural residues in the form of straw have largely been used as bedding and feed in animal husbandry. Other uses include mulch in horticulture and vegetable cultivation for protection against frost and as growth substrate for the production of mushrooms, as well as for electricity and heat production, among other uses.[249,250] Another important application is incorporation into the soil following harvest to ensure levels of SOC, which is critical for maintaining organic matter balance and nutrient cycles in soil. Excessive residue removal can significantly limit the long-term productivity of soils. Historically, straw has also been burned in the field, but this practice has been banned in Europe in recent years for air quality reasons. Straw harvest should be limited to ensure that sufficient levels of SOC are maintained. As straw is a residue, reuse is not relevant. Material recycling is the highest value retention option in the waste hierarchy, followed by recycling as feedstock for biofuel production.

Scarlat et al. (2019) estimated that the total annual sustainable crop residue availability in the EU-27 from wheat, rye, barley, oats, maize, rice, rapeseed, and sunflower was 113,419,000 kilotons of dry matter using yield data from 2000 to 2015.[249] Sustainable in this

246 UK Government. (2017). Annex IX factsheet - Municipal Solid Waste. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/277600/annexIX-factsheets.pdf.
247 Peng et al. (2022). Recycling municipal, agricultural and industrial waste into energy, fertilizers, food and construction materials, and economic feasibility: a review. Recycling municipal, agricultural and industrial waste into energy, fertilizers, food and construction materials, and economic feasibility: a review | SpringerLink.
248 Institute for Sustainable Process Technology. (2023). Waste as a feedstock for the chemical industry, Waste as a feedstock for the chemical industry – ISPT.
249 Scarlat et al. (2019,).Integrated and spatially explicit assessment of sustainable crop residues potential in Europe. https://www.sciencedirect.com/science/article/abs/pii/S0961953419300303.
250 Ecofys. (2013). Low ILUC potential of wastes and residues for biofuels: straw, forestry residues, UCO, corn cobs. https://library.wur.nl/WebQuery/titel/2043714.

context means that technological (current machinery not being able to separate all residue from crop yield) and environmental (maintaining sufficient levels of SOC) constraints are taken into consideration.

Ugolini et al. (2022) concluded that regions in Central and Mediterranean Europe had the highest cereal straw bioeconomic potentials. They estimated that Central Europe has an overall potential of 16.249 kt (232.359 TJ), 70% of which in France and Germany, and the Mediterranean region 3541 kt (50.630 TJ).[251]

Corn stover

Corn stover consists of residual harvesting material, such as stalks and leaves. For each kg of corn, roughly a kg of stover is also produced. As with straw, a fraction of corn stover residues need to remain on the field to ensure SOC levels remain sufficient. Due to its high carbohydrate content, it can be used to produce bioethanol. Corn stover can also serve as a feedstock for the production of value-added and platform chemicals.[252] Other applications include use for animal bedding or feed and for electricity or heat generation. Like cereal straw, corn stover is a residue and cannot be reused. Next to ensuring enough is left on the field, recycling is the highest valorization option within the waste hierarchy. Issues related to resource competition and recent numbers on exact supply or availability potential were not found in literature. However, Imperial College London consultants recently estimated that corn stover supply potential for 2030 will lie between 118,000 and 141,000 kilotons (47,000 to 57,000 ktoe) and it is expected that current numbers will not be much different from these numbers.[253] Considering the amount of stover produced during corn production and the large amounts of corn produced in Europe, the current use for biofuels and biogas production do not seem to be in excessive competition with other uses.

Overall, 9 ktoe of straw and corn stover-based biofuels and biogas were used in transport 2021 and 5 ktoe in 2020. Before then, fuel produced from this feedstock was not used at all.[236]

f) Animal manure and sewage sludge;

Animal manure (liquid slurry and solid)

Traditionally, animal manure has been used as a fertilizer in agriculture due to its high nitrogen content, but this can lead to environmental problems including soil and water contamination and pollution, as well as odors.[254] Furthermore, its natural degradation leads to fugitive emissions of both methane and carbon dioxide during storage. Animal manure can also be used for biogas production.[254] Application as feedstock for biofuel production therefore results in multiple environmental benefits. Its residue after biogas production can still be used as fertilizer, meaning there is additional economic benefits as well. Based on these two factors, the risk of resource competition appears low.[255] Regarding the waste hierarchy, prevention of manure production would be the ideal scenario, but this would require a reduced total number of livestock and ultimately, a change in consumer dietary preferences. As reusing is not an option since manure is waste and has no predetermined use, and since recycling manure as fertilizer come with the aforementioned disadvantages,

251 Ugolini et al. (2022) Novel Methodology to Assess Advanced Biofuel Production at Regional Level: Case Study for Cereal Straw Supply Chains https://www.mdpi.com/1996-1073/15/19/7197

252 Pan et al. (2019) Integrated Processing Technologies for Food and Agricultural By-Products Integrated Processing Technologies for Food and Agricultural By-Products | ScienceDirect.

253 Panoutsou & Maniatis. (2021). Sustainable biomass availability in the EU, to 2050. Sustainable biomass availability in the EU, to 2050 - Concawe.

254 Scarlat et al. (2018). A spatial analysis of biogas potential from manure in Europe. https://www.sciencedirect.com/science/article/pii/S1364032118304714.

255 Guidehouse. (2023). Beyond energy – monetising biomethane's whole-system benefits. 20230213_guidehouse_eba_report.ashx.

recycling manure as feedstock for biofuel production is the highest value retention option over direct burning (of dry manure) for energy generation.[254]

Scarlat et al. (2018) calculated that 1,080,000 kilotons of manure are produced in the EU each year from all types of livestock combined, of which 770,990 are collectible (excluding the UK), based on the number of cattle and their average manure production.[254] Elbersen et al. estimated in 2016 that the total EU-28 manure that can potentially be collected is 76,000 kilotons.[256]

Sewage sludge

Sewage sludge is the product that remains after wastewater with a high concentration of organic materials (both industrial and municipal) has been treated via aerobic treatment. Next to serving as a feedstock for biogas production, sewage sludge can be used as fertilizer and can be incinerated for energy and ash production.[257] The European Biogas Association[258] (EBA) proposes the following waste hierarchy to be developed and implemented so that wastewater, from which sludge is produced, is valorized in an optimal way:

1. **Prevention**: produce as little wastewater as possible
2. **Reuse** of water in production processes where possible
3. Treatment of wastewater **with energy recovery**
4. Treatment of wastewater **without energy recovery**

According to the EBA, 17,000 kilotons (dry matter) of sewage sludge is produced annually in Europe from industrial wastewater, whereas 8,369 kilotons of sewage sludge was produced from municipal wastewater in 2018.[259] In the same year, sewage sludge-based biofuel and biogas use in transport was 66 ktoe, which has since then increased to 104 ktoe in 2021.[236]

g) Palm oil mill effluent and empty palm fruit bunches;

Palm oil mill effluent (POME)

Palm oil mill effluent, or POME, arises during palm oil processing. It contains 90-95% water in its raw form, as well as residual oil, soil particles, and suspended solids.[260] Around 0.65 kiloton of POME is produced for every kiloton of fresh palm branches processed. It is a highly polluting material, that not only requires treatment before disposal, but also emits significant amounts of fugitive methane (25 m^3 per m^3 of POME produced). In terms of bioenergy production, the primary conversion pathway is anaerobic digestion into biogas. However, research has been done into using POME for fatty acid methyl ester production and biodiesel.[261,262] Besides discharge, no alternative applications are currently available, meaning recycling it as feedstock is the highest option within the waste hierarchy and resource competition is low. No production takes place within the EU, but import from South-

256 Elbersen et al. (2016). Outlook of spatial biomass value chains in EU-28. Elbersen_et_al_2016_Outlook_of_spatial_biomass_value_chains_in_EU28_(D2.3_Biomass_Policies).pdf (iinas.org).
257 Sludge Processing. (2020). Incineration of sludge. Incineration of sludge | Sludge Processing.
258 European Biogas Association. (2021). The role of biogas production from industrial wastewaters in reaching climate neutrality by 2050. The role of biogas production from industrial wastewaters in reaching climate neutrality by 2050 | European Biogas Association.
259 Gas for Climate. (2022). Biomethane production potentials in the EU Excel.
260 Feedipedia. Palm oil mill effluent. https://www.feedipedia.org/node/15395.
261 Flabsong, M., et al. (2016). Feasibility study of biodiesel production from residual oil of palm oil mill effluent International Journal of GEOMATE. http://www.geomatejournal.com/sites/default/files/articles/60-64-2568-Monthatip-May%202017-33-g3.pdf.
262 UK Department for Transport. (2018). Renewable Transport Fuel Obligation statistics: period 9 2016/17, report 6. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/681174/rtfo-year-9-report-6-revised.pdf.

East Asia does occur and has been on the rise since 2018.[263] In 2020, 104,625,000 kilotons of POME was imported from Malaysia, the world's second largest producer of palm oil after Indonesia. In 2021, this had risen to 165,769,000 kilotons, which represents a 58% increase. This trend is expected to continue in the future.

Empty palm fruit bunches

Empty palm fruit bunches (EFBs) are another residue of the palm oil processing industry. Around 0.20-0.22 kilotons of EFBs are produced for every kiloton of fresh palm branches processed.[260] It can be used for pyrolysis oil production, for electricity and heat generation, as paper and fibreboard material, and as fertilizer (after composting or incineration to ash).[264] As it is a residue, it cannot be reused, meaning recycling as feedstock is the highest waste hierarchy option possible. Resource competition again seems to be low. Additionally, it is unclear how much is imported into the EU. No production takes place inside the EU.

The use of biofuels and biogas in transport within the EU-27 based on both POME and EFBs combined has risen sharply over the past years from 3 ktoe in 2016 to 695 ktoe in 2021, which is in line with the reported increase in POME imports.[236]

h) Tall oil pitch;

Tall oil pitch is generated by fractional distillation of crude tall oil (CTO), a co-product of the paper and pulp industry, with a yield of 15-40%. It can serve as a feedstock for HVO production. Other applications are use as adhesive and sealant, as well as lubricant or grease.[265] No information was identified on its EU supply or potential, but it is understood that the utilization rate of CTO is already high and increased biofuel demand could lead to an increase in raw material prices.[266] Biofuel and biogas use produced from tall oil pitch in transport was 10 ktoe in 2021.[236] Interestingly, this number was 124 ktoe in 2020, whereas it was 1 ktoe in both 2019 and 2018 and 0 ktoe the two years prior.

i) Crude glycerine;

Crude glycerine, also known as glycerol, is a residue of biodiesel production arising during transesterification. Different grades with varying levels of glycerol, methanol, and water are available. Approximately 1 ton of crude glycerine is generated for every 10 tons of FAME biodiesel produced.[267] In terms of biofuel production, crude glycerine can be used for biomethanol production via gasification to syngas and methanol synthesis. When purified, refined glycerine can be used in a wide range of other applications (>1,500) in the chemical industry, as a food preservative, and in the cosmetics and pharmaceutical industries.[267,268,269] Crude glycerine can otherwise be used as animal feed or in cement production. As glycerine is a residue, material recycling represents the highest value option within the waste hierarchy, followed by recycling as biofuel feedstock.

50-70% (600-800 kilotons) of crude glycerine was refined in 2016, 25-35% (300-400 kilotons) was used as animal feed and, 100 kilotons were used for heat and electricity

263 MPOC. (n.d.). EU-27 Biofuels Outlook – Market Trending Towards Advanced Biofuels. EU-27 Biofuels Outlook – Market trending towards advanced biofuels – MPOC.
264 Safana A. A. et. al. (2017). Potential Application of Pyrolysis Bio-Oil as a Substitute for Diesel and Petroleum Fuel, Journal of Petroleum Engineering & Technology. (PDF) Potential Application of Pyrolysis Bio-Oil as a Substitute for Diesel and Petroleum Fuel (researchgate.net).
265 European Chemicals Agency. (n.d.). Substance Information - ECHA (europa.eu).
266 Morris, C. (2016). EU CTO – Added Value Study, Fraunhofer Umsicht. EU CTO – Added Value Study (harrpa.eu).
267 Yang et al. (2012). Value-added uses for crude glycerol--a byproduct of biodiesel production. https://biotechnologyforbiofuels.biomedcentral.com/articles/10.1186/1754-6834-5-13.
268 Fan et al. (2010). Glycerol (Byproduct of Biodiesel Production) as a Source for Fuels and Chemicals – Mini Review. https://pdfs.semanticscholar.org/7a9f/f1249338683b50e6aac00d1eb40167c9b2ce.pdf.
269 Cerulogy. (2017) Waste not want not. Understanding the greenhouse gas implications of diverting waste and residual materials to biofuel production. http://www.cerulogy.com/wp-content/uploads/2017/09/Cerulogy_Waste-not-want-not_August2017.pdf.

generation.[270] Most of the global glycerine production (63% in 2018) is derived from the biodiesel industry. The remaining fraction is mainly supplied by the soap and fatty acid industries. It is estimated that global crude glycerine production will reach 6.3 million tons by 2025, of which roughly 26% or 1.64 million tons will be produced by the EU.[271] An imbalanced market could arise due to an excess supply of crude (bio-)glycerol resulting from the development of the biodiesel industry, as global demand is expected to be only 4 million tons in 2025. In 2021, glycerine-based biofuels and biogas use in transport in the EU-27 was relatively low with 27 ktoe, meaning eventual growth could be accommodated for if an imbalanced market will indeed develop.

j) Bagasse;

Bagasse is fibrous matter remaining after sugarcane or sorghum are crushed for sugar juice extraction. 110-160 kg of bagasse is generated for every tonne of sugar cane produced. It can be used as feedstock for bioethanol production.[272] Butanol production from bagasse has also been explored.[273] Other applications are as fibreboard filler, in paper production, as feedstock for biodegradable plastics and animal feed, and for heat and electricity generation.[274,275] As a residue, material recycling of bagasse represents the highest waste hierarchy option possible. EU production is negligible with only Spain producing small quantities.[276] The same goes for imports, likely due to transport costs and a limited number of EU biorefineries being able to process this feedstock. Overall, EU-27 use of bagasse-based biofuels and biogas in transport was only 8 ktoe in 2021.[236]

k) Grape marcs and wine lees;

Grape marcs and wine lees are both processing residues from the wine-making industry.[277] Grape marcs, also known as pomace, is the substance left after fresh grapes have been pressed and contains skins, pulps seeds, and stems. Wine lees is the sediment left over in winemaking vessels and consists of dead yeasts and other solids. Both residues are often mixed and can be fermented to produce bioethanol.[278] Gasification to syngas and anaerobic digestion to produce biogas are alternative conversion pathways. Since 2008, however, EU legislation obliges all grape marc and wine lees to be fermented to bioethanol.[279] Previous applications included use as mulch, organic fertilizer, or animal feed. Nowadays, this feedstock is also used to produce other wine products and spirits such as Ripasso.[280] Considering a reduction of wine production and therefore processing residue generation is unlikely, and since reusing grape marcs and wine lees is not an option, material recycling is the highest value retention option possible.

270 Greenea. (2016). European waste-based biodiesel and glycerin markets. https://www.greenea.com/wp-content/uploads/2016/09/Greenea-Presentation-July-2016.pdf.
271 Attarbarchi et al. (2023). New trends on crude glycerol purification: A review. New trends on crude glycerol purification: A review - ScienceDirect.
272 SugarCane.org; http://sugarcane.org/ethanol/.
273 Jim Lane. (2013). Brazil's Big Six in advanced biofuels & chemicals: who's doing what now?. http://www.biofuelsdigest.com/bdigest/2013/09/16/brazils-big-six-in-advanced-biofuels-chemicals-whos-doing-what-now/.
274 Salman Zafar. (2018) Energy Potential of Bagasse. https://www.bioenergyconsult.com/tag/properties-of-bagasse/.
275 Bagasse (sugarcane). Greenbox. https://www.biologischverpacken.de/en/bagasse-sugarcane.
276 UNdata. (2018). Bagasse. http://data.un.org/Data.aspx?d=EDATA&f=cmID%3aBS%3btrID%3a01.
277 E4tech. (2014). Advanced Biofuel Feedstocks – An Assessment of Sustainability. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/277436/feedstock-sustainability.pdf.
278 New Atlas. 2015. Winetasting waste could be raw material for biofuel, https://newatlas.com/biofuel-winemaking-byproduct/39031/.
279 European Commission. (2015). DIRECTIVE (EU) 2015/1513 of the European Parliament and of the Council of 9 September 2015 amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable sources. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015L1513&from=EN.
280 UK Government. (2017). Annex IX factsheet. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/277600/annexIX-factsheets.pdf

In the EU, 5,600 kilotons of grape pomace are produced annually as by-product of the winemaking industry.[281] No recent numbers were found for wine lees. Use of biofuels and biogas in transport produced from this feedstock has remained relatively stable over the past years, with 39 ktoe used in 2019, 32 ktoe used in 2020, and 38 ktoe used in 2021.[236]

l) Nut shells;

Nut shells are the outer hard casing of nuts leftover after the edible insides have been removed during processing. Nut production in the EU mainly involves almond, walnut and, hazelnut.[282] Nut shells can be used as feedstock to produce biodiesel via gasification and Fischer-Tropsch synthesis.[283] They can also be used to produce syngas and be burnt for heat and electricity generation.[284,285] Competing uses in heat and electricity and industry are high, and displacing walnut shells in manufacturing, cleaning, polishing, and the cosmetics industry with alternatives like silica could lead to increases human health risks.[282] As nut shell generation cannot be prevented, as long as nut production does not decrease, and considering there are no options for reuse, material recycling of nutshells is the highest waste hierarchy option possible.

Based on 2018 FAOstat data, nut shell generation is estimated to be in the region of 500 kilotons per year.[286] This relatively small supply is reflected in the limited use of biofuels and biogas based on this feedstock in transport, with only 1 ktoe used in 2020 and 2021 and none in the years prior.[23626] Limited supply is not the only cause for this, as there are only a small number of gasification-to-biofuels plants operational in Europe.

m) Husks;

Husks are the protective outer layers of seeds, nuts, grains, and fruits and are generated when these agricultural products are processed. Olive cores and pulp are sometimes also included in this feedstock category.[287] Husks can be used as raw material to produce bioethanol. Other applications include industrial applications as a silica substitute, as well as for fertilizer, domestic fuel, whole crop silage, and animal feed. However, heat and electricity generation is the primary competitive use. No biofuels or biogas based on this feedstock are currently being used in transport across the EU-27.[236]

n) Cobs cleaned of kernels of corn;

This feedstock can be used for bioethanol production, but this is currently not done in the EU. Many other applications in industry, food production, and heat and electricity generation exist. Biofuels and biogas based on this feedstock are not being used in transport in the EU-27.[236]

o) Biomass fraction of wastes and residues from forestry and forest-based industries, namely, bark, branches, pre-commercial thinnings, leaves, needles, tree tops, saw dust, cutter shavings, black liquor, brown liquor, fibre sludge, lignin and tall oil;

281 LIFE 3.0 - LIFE Project Public Page (europa.eu).
282IEEP. (2013). The sustainability of advanced biofuels in the EU – Assessing the sustainability of a list of wastes, residues and other feedstocks set out in the European Commission's proposal on Indirect Land Use Change (ILUC). https://ieep.eu/publications/the-sustainability-of-advanced-biofuels-in-the-eu.
283 E4tech, 2014, Advanced Biofuel Feedstocks – An Assessment of Sustainability, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/277436/feedstock-sustainability.pdf
284 The Dixon Ridge BioMax Success Story. 14-03-28 dixon ridge success story.pdf (gocpc.com).
285 Bioenergy Consult. (2018). Energy Potential of Palm Kernel Shells. https://www.bioenergyconsult.com/?s=nut+shells.
286 Noszczyk et al. (2021). Kinetic Parameters of Nut Shells Pyrolysis. Energies | Free Full-Text | Kinetic Parameters of Nut Shells Pyrolysis (mdpi.com).
287 IEEP. (2013). The sustainability of advanced biofuels in the EU – Assessing the sustainability of a list of wastes, residues and other feedstocks set out in the European Commission's proposal on Indirect Land Use Change (ILUC). https://ieep.eu/publications/the-sustainability-of-advanced-biofuels-in-the-eu.

This feedstock category includes a wide range of ligno-cellulosic materials and is therefore suited for various forms of biofuel production: bioethanol via hydrolysis and fermentation, biomethanol by gasification, and drop-in fuels production via pyrolysis. The highest quality fractions of this feedstock, such as pulp logs and sawmill chips, can also be used in the pulp and panel industries, whereas lower quality fractions like sawdust, bark, and harvest residues are currently only used for energy production. Highest waste hierarchy options differ per exact feedstock subtype, but material recycling should be prioritized over biofuel production. There are indications that increased biofuel production from forestry residues could lead to a rise in feedstock prices and therefore, negatively impact fibreboard and particleboard production.[288]

While no current supply numbers were found in literature, overall EU forestry residues potential is expected to be 65,000 kilotons in 2025.[289] The use of biofuels and biogas in transport based on this feedstock was 224 ktoe in 2021, which represents a significant increase from 2020 (34 ktoe) when use dipped, as 2019 use was 134 ktoe. Interestingly, this 2020 dip in use took place at the same time when the use of tall oil pitch-based biofuels and biogas peaked. A potential explanation for this could be changes in MS reporting classifications.

p) Other non-food cellulosic material**;**

According to EC implementing regulation 2022/996 Annex IV, examples of feedstocks included in this category are soy hulls, agricultural harvesting residues, and unused feed/fodder from ley.

q) Other ligno-cellulosic material **except saw logs and veneer logs.**

According to EC implementing regulation 2022/996 Annex IV, examples of feedstocks included in this category are palm fronds, palm trunks, damaged trees, and recycled and waste wood.

Part B

a) UCO

UCO is generated as residue from restaurant and home kitchens, and therefore, its generation can never be prevented completely. It is estimated that in Asia, a significant amount of UCO is currently reused in the form of illicit 'gutter oil' (recycled oil used for cooking which negatively effects public health), but this practice should not be stimulated, as it is shown that this is detrimental to human health.[290,291] Therefore, recycling UCO is the highest value retention option in the EU's waste hierarchy principles. Although various applications exist in the oleochemical industry, as well as in energy recovery, UCO as a feedstock for diesel production is its primary application and it is generally expected that this will remain so, mostly due to the related economic and regulatory incentives.[290] In their 2020 report on UCO and its use as a biofuel, CE Delft note that at 18.5%, UCO was the third most used feedstock for biodiesel production in 2019 after rapeseed oil (37%) and

288 Bryngemark. (2019). The Competition for Forest Raw Materials in the Presence of Increased Bioenergy Demand. FULLTEXT01.pdf (diva-portal.org).
289 Di Gruttola & Borello. (2021). Analysis of the EU Secondary Biomass Availability and Conversion Processes to Produce Advanced Biofuels: Use of Existing Databases for Assessing a Metric Evaluation for the 2025 Perspective. Sustainability | Free Full-Text | Analysis of the EU Secondary Biomass Availability and Conversion Processes to Produce Advanced Biofuels: Use of Existing Databases for Assessing a Metric Evaluation for the 2025 Perspective (mdpi.com).
290 CE Delft. (2020). Used Cooking Oil (UCO) as biofuel feedstock in the EU. https://ce.nl/publicaties/used-cooking-oil-uco-as-biofuel-feedstock-in-the-eu/.
291 ICCT. (2022). An estimate of current collection and potential collection of used cooking oil from major Asian exporting countries. https://theicct.org/publication/asia-fuels-waste-oil-estimates-feb22/.

palm oil (30%).[290] Increased use of UCO and rapeseed oil have resulted in the overall growth of EU biodiesel production from 2016 to 2019.

According to CE Delft, EU+UK UCO demand was 2,800 kilotons in 2019.[290] They expect that this will have grown to 6,100 to 6,400 kilotons per year by 2030, which could lead to various displacement effects in and outside the EU. Whereas some of these could be positive, such as the displacement of UCO as 'gutter oil' in China, most will likely be negative and lead to increased ILUC as UCO will be replaced by virgin oil, often palm.

CE Delft estimates the total amounts of UCO produced in the EU to range from 700 to 1,200 kilotons per year, with a further 1,400 kilotons being imported.[290] According to Greenea, however, 576 of the 691 kilotons UCO available from the professional sector, or 83%, were collected in the EU (UK excluded) in 2016.[292] This number was considerably lower in the household sector, from which roughly 40 kilotons of UCO was collected in 2016, whereas the potential collectable household UCO was around 812 kilotons (UK excluded). Only 5% of all potential household UCO was collected, meaning there is significant progress to be made. Fractions of household UCO collected as fraction of total UCO collection vary significantly per MS, from 0% in Denmark to 45% in Belgium, according to CE Delft.[290] Greenea even estimated that 64% of all household UCO is collected in Belgium.[292] In both sectors combined, 616 of the 1503 kilotons available was collected, meaning the total collection rate was 41% in 2016.

In 2019, 62% of UCO processed into biofuels in the EU was imported.[293] A significant fraction of this (75%) comes from Asia (China, Indonesia, and Malaysia), with Russia, the USA, and Saudi Arabia also being important suppliers.[290] CE Delft estimated that the total supply to the EU from these regions is in the range of 2,100 to 2,700 kilotons per year. Based on UN data, the International Council on Clean Transportation (ICCT) states that 68% of total 2019 UCO imports into the EU come from Asia and the USA. Furthermore, they estimate that even though there currently appears to be a surplus of UCO in Asia's top six producing countries (China, India, Indonesia, Japan, Malaysia, and South Korea) that could be accessed for additional exports, this might change in the future with increased demand arising from the REDII and presumably FuelEU Maritime. The ICCT estimates the EU demand for UCO imports could grow to 3,500 kilotons in 2030 and 5,600 kilotons in 2035, which would be a sizeable fraction of the 3,700 to 3,500 kilotons that are currently collected in the six countries studied. EU demand could even grow further due to other uncapped initiatives, which are not considered for this estimation. Therefore, the ICCT advises to implement caps on the use of UCO in the ReFuelEU Aviation and FuelEU Maritime to stimulate the development of new technologies so that the risk of overreliance on UCO as a feedstock is limited.

UCO-based biofuel and biogas use in transport is by far the highest out of all the Annex IX feedstock biofuels, with 2,580 ktoe used in 2021.[236] However, use growth rate has stagnated somewhat relative to the years prior.

b) Animal fats classified as categories 1 and 2 in accordance with Regulation (EC) No 1069/2009S

Category 1 and 2 animal fats belong to ABPs, which are separated at the slaughterhouse or result from the mortality of non-meat animals. In their 2019 statistical overview, the European Fat Processors and Renderers Association (EFPRA) published the availability of

292 Greenea. (2016). Analysis of the current development of household UCO collection systems in the EU. [Greenea-Report-Household-UCO-Collection-in-the-EU_ICCT_20160629.pdf (theicct.org)](Greenea-Report-Household-UCO-Collection-in-the-EU_ICCT_20160629.pdf).
293 Euractiv. (2019). Fraudulent Used Cooking Oil biodiesel – bad for the climate and a blow to EU farm, oilseed and plant protein sectors. Fraudulent Used Cooking Oil biodiesel – bad for the climate and a blow to EU farm, oilseed and plant protein sectors – EURACTIV.com.

the three different categories of animal fats and meal, as set out in Regulation (EC) 1069/2009.[294] Of these categories, only the fraction that is animal fat within categories 1 and 2 are included in Annex IX Part B. In 2019, a total of approximately 583 kilotons of these feedstocks were available according to the EFPRA. Due to improvements in separation, the production of category 3 fats has increased relative to categories 1 and 2 over recent years. It is estimated that 90% of all EU animal waste processers are affiliated with the EFPRA, implying the actual total feedstock availability could be higher. Of the 583 kilotons reported by the EFPRA, 522 kilotons were used to produce biodiesel. The remaining 61 kilotons were used for combustion. A negligible fraction was used as a feedstock for the oleochemical industry. Next to energy recovery, which is a lower value retention option in the waste hierarchy, and use as a feedstock in the oleochemical industry, no other uses currently appear to be known for this feedstock next to recycling it as a feedstock for biofuel production.[295, 296] Animal fat-based biofuel and biogas use in transport was 793 ktoe in the EU-27 in 2021 and has shown a steady increase over the years.[236]

4.6. ILUC science update

The aim for this section is to provide an overview of the most recent studies on indirect land-use change (ILUC), including models and reports, to provide a description of recent work and any updates on estimated ILUC factors or ILUC impacts. This can then be compared with the previous work for the EC to see if the range of uncertainty can be narrowed. We will also focus on whether there are studies that take into account the most recent Union policy developments (e.g., ILUC limiting factors in the RED, MS limits on particular feedstocks (palm and soy) for biofuels, broader deforestation-free commodity commitments at EU level, etc.).

4.6.1. Overview of models assessing Union policy impacts on ILUC

Modeling and estimating ILUC in regard to bioenergy is challenging due to various issues that arise including different assumptions and set up, lack of consensus on terminology, insufficient data, to name a few.[297] Oftentimes, this results in a wide variety of conclusions and makes it difficult to place ILUC estimates in policy. Generally, three categories of ILUC models are available: economic, casual-descriptive, and normative.

Economic models use prices of goods and elastisticies at equilibrium; the system is evaluated based on how it reaches a new equilbrium after a shock.[298] Such models are extremely complex and normally require highly trained operators to carry out the model and interpret results. Examples of economic models include: Forest and Agricultural Sector Optimization Model (FASOM), Common Agricultural Policy Regionalised Impact (CAPRI), and Food and Agricultural Policy Research Institute – Center for Agricultural and Rural Development (FAPRI-CARD). Casual-descriptive (CD) models are based on cause-effect relationships, which are determined based on "biological and physical land characteristics,

294 European Commission. 2021. Assessment of the potential for new feedstocks for the production of advanced biofuels. Assessment of the potential for new feedstocks for the production of advanced biofuels - Publications Office of the EU (europa.eu)

295 Byrne, Jane. (2023). Concerns over climate impacts and potential fraud from use of animal fats in transport fuel. https://www.feednavigator.com/Article/2023/06/14/Concerns-over-climate-impacts-and-potential-fraud-from-use-of-animal-fats-in-transport-fuel.

296 Bondiolo et al. (2019). Animal fats for non-food uses. A review of technology and critical points. animal_fats_for_non-food_uses._a_review_of_technology_and_critical_points.pdf (innovhub-ssi.it).

297 Kline, K. L. & Dale, V. H. (2023). Reality is a special case, IEA Bioenergy webinar. https://www.ieabioenergy.com/wp-content/uploads/2023/06/ILUC_KLINE-DALE.pdf.

298 Balugain, E., Sumfleth, B., Majer, S., Marazza, D., & Thraen, D. (2022). Bridging Modeling and Certification to Evaluate Low-ILUC-Risk Practices for Biobased Materials with a User-Friendly Tool. https://doi.org/10.3390/su14042030.

price elasticities, statistical data, etc."[298] Life-cycle assessment (LCA) accounting models are one example of a CD model. Finally, normative models use statistical data to make assumptions, but these models oftne do not distinguish between direct and indirect impacts.

The latest efforts of the EC has been focused on mitigating ILUC, as seen in the various Horizon-2020 projects (see section 4.6.2), the High ILUC project (Lot 1[299]) to assess the expansion of biofuel crops into high carbon stock area, and the Low ILUC Certification project (Lot 2[300]) that aims to test the sustainability and certification of Low ILUC feedstocks for biofuel applications. The 2008 GLOBIOM model was initially developed to assess climate change mitigation policies on bio-based industries, such as biofuels, and agricultural and forest markets, by forecasting ILUC impacts until 2100. This model was used in 2016 by Ecofys, IIASA and E4Tech to make policy scenarios with corresponding ILUC-estimations[301] and in 2020 to estimate LULUCF-emissions[302]. Since then, other models have been developed that predict ILUC estimates, such as the 2022 SydILUC-model (a CD model) developed for the Horizon-2020 project STAR-ProBio[303] in line with REDII methodology. This model assesses ILUC associated with biobased materials.

4.6.2. Overview of ongoing Horizon-2020 projects

The EC is currently funding several ongoing research projects under Horizon-2020 including projects related to the mitigation of ILUC, high value application of ILUC feedstocks, marginal and contaminated land, the diversification of farming systems, governance, and feedstock sustainability. This section provides an overview of the specific projects and project goals under each of the aforementioned categories. For each project, the project code, title, duration, and a project link are also included.

High value application of ILUC feedstock

- HORIZON-CL6-2021-CIRCBIO-01-06: Contained biomass solutions for sustainable and zero-Indirect Land Use Change (ILUC) production systems for high value applications; 22 June 2021 – 06 October 2021; https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-cl6-2021-circbio-01-06. This project examines two possibilities for Low ILUC applications on bio-based innovations such as aquatic biological resources and blue biotechnology or enhanced cooperation in forestry by establishing an 'open innovation ecosystem' with relevant stakeholders to sustainably harvest ILUC feedstocks. There were no applications for this project.
- HORIZON-CL6-2023-CircBio-02-3-two-stage: Non-plant biomass feedstock for industrial applications: technologies and processes to convert non-lignocellulosic biomass and waste into bio-based chemicals, materials and products, improving the cascading valorisation of biomass; 22 December 2022 – 26 September 2023; https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-cl6-2023-circbio-02-3-two-stage. This project aims to develop diverse innovative value-chains for the bio-based (industrial) sectors, such as Low ILUC non-Lignocellulosic Biomass (aquatic and terrestrial) for non-bioenergy purposes.
- HORIZON 2020 grant agreement No. 745012: The GRACE Project: GRowing Advanced industrial Crops on marginal lands for biorEfineries; 1 June 2017 – 31 December 2022; https://cordis.europa.eu/project/id/745012: This project aims to demonstrate 10 complete value chains and industry-relevant scales using Low ILUC

299 https://iluc.guidehouse.com/lot-1
300 https://iluc.guidehouse.com/lot-2
301 ILUC Quantification Study of EU Biofuels | Project Transparency Platform – by Ecofys, IIASA and E4tech (globiom-iluc.eu)
302 Frank et al. (2020). Documentation for estimating LULUCF emissions / removals and mitigation potentials with GLOBIOM/G4M. https://climate.ec.europa.eu/system/files/2021-08/lulucf_methodology_report_en.pdf
303 http://www.star-probio.eu/

feedstocks on degraded and contaminated soils. End uses include insulation material, mycelium-based panels, particle boards and lightweight concrete for the building sector, azelaic acid phenols, HMF, ethanol, and butandiol for the chemical sector, pelargonic acid for the agricultural sector, non-psychotropic cannabinoids for the medicinal and cosmetics sector, and lastly, composites for the automotive sector.

Marginal and contaminated land

- HORIZON-CL6-2022-CIRCBIO-01-02: Marginal lands and climate-resilient and biodiversity-friendly crops for sustainable industrial feedstocks and related value chains; 28 October 2021 – 15 February 2022; https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-cl6-2022-circbio-01-02. Projects include 'MIDAS Utilization of Marginal lands' for growing sustainable industrial crops and developing innovative bio-based products and 'MarginUp Raising the bio-based industrial feedstock capacity of Marginal Lands'. These projects examine the possibilities of degraded and contaminated land to provide additional feedstock, while improving and restoring the soil quality and biodiversity of the regions. MIDAS builds on the previous work done by the same consortium 'MAGIC', where various types of marginal land in Europe is mapped to create a better insight on Low ILUC potential within Europe. MIDAS examines optimization of industrial crops and innovative cropping systems to create additional yield, including, but not limited to, intercropping, agroforestry, new breeding tools for hemp and miscanthus, sub water retention systems, and biochar.
- HORIZON 2020 grant agreement No. 101006873: GOLD Bridging the gap between phytoremediation solutions on growing energy crops on contaminated lands and clean biofuel production; 1 May 2021 – 30 April 2025; https://cordis.europa.eu/project/id/101006873. Aim is to research and develop methods to produce biofuels on contaminated land, while removing soil pollutants through phytoremediation. Crops such as miscanthus, sorghum, switchgrass, and industrial hemp are high-yielding and are able to grow on metal-contaminated lands. Five of the polluted pilot sites are in Europe and two are in China. Pollution sources range from lead and zinc smelters, to mining, agriculture, and landfill sites.
- Forte Supply and application of fibre crops for sustainable soil remediation and bio-based raw material production for industrial uses; 14 November 2019 – 13 November 2022; https://www.forte-project.gr/. This project also aims to grow feedstock on contaminated soils by using fast growing high-yielding fibre crops and additionally, cleaning up the polluted sites through phytoremediation. The polluted sites are former mining areas and agricultural sites. Where GOLD focuses more on growing additional yield, Forte focuses more on the phytoremediation benefits of the crops by measuring which crop uptakes the most metals and can then create a roadmap of which crops are most suitable to use per pollution scenario. Additionally, Forte looks at the metal uptake of food crops (such as lemons, aubergines, cabbages, etc.) and finds other value-added (non-bioenergy) uses for these feedstocks that exceed maximum permissible values of toxins and metals in edible vegetables.
- HORIZON 2020 grand agreement No. 789562: BIO4A Advanced sustainable BIOfuels for Aviation; 1 May 2018 – 30 June 2023; https://cordis.europa.eu/project/id/789562. Project aims to accelerate the deployment of sustainable aviation fuels (SAF) by upscaling HEFA used cooking oil and to investigate alternative Low ILUC feedstock possibilities by growing oil crops on severely degraded lands in Europe.

Diversification of farming systems

- HORIZON-CL6-2022-CIRCBIO-01-04: Maximising economic, environmental and social synergies in the provision of feedstock for bio-based sectors through diversification and increased sustainability of agricultural production systems; 28 October 2021 – 15 February 2022; https://cordis.europa.eu/programme/id/HORIZON_HORIZON-CL6-2022-CIRCBIO-01-04. Project 'CARINA CARinata and CamelINA' aims to boost the sustainable diversification in EU farming systems. CARINA focuses of improving sustainable farm management and increasing yield sustainably by introducing a diverse cropping system, such as introducing camelina and carinata to the existing crop rotation.

Governance

- HORIZON-CL6-2023-GOVERNANCE-01-7: Integrated assessment of land use and biomass demands to contribute to a sustainable healthy and fair bioeconomy; 22 December 2022 – 23 March 2023; https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-cl6-2023-governance-01-7. This project aims to create better understanding, methods, and tools for determining the potential and limits of land and biomass to contribute to the climate, biodiversity, environmental, as well as social and economic objectives of the European Green Deal. Furthermore, it will also improve knowledge of policy pathways to maximise the climate value of bio-economic solutions within ecological limits and improve decision making to ensure policy cohesiveness at national and regional levels.

Feedstock sustainability

- HORIZON-JU-CBE-2022-S-01 Developing and validating monitoring systems of environmental sustainability and circularity: collection of best practices and benchmarks; 22 June 2022 – 22 September 2022; https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-ju-cbe-2022-s-01. This project aims to evaluate existing methods and develop new methods to assess ILUC risks of bio-based systems and demonstrate low ILUC levels.
- HORIZON -JU-CBE-2023-S-02 Supporting the capacity of regions in environmental sustainability assessment for the bio-based sectors; 26 April 2023 – 20 September 2023; https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-ju-cbe-2023-s-02. This project aims to improve understanding and awareness among regional and local stakeholders of sustainability and circularity screening methods (such as water usage, biodiversity impacts, land use potentials and limitations, and biological primary and secondary feedstocks). Furthermore, the project aims to support and develop bio-based sectors and applications through higher innovation capacity and local action plans based on local resources.

4.7. Union database

Article 28 of the REDII includes provisions that require the EC and MSs to strengthen cooperation between national systems, as well as between national systems and voluntary schemes and verifiers (including, where appropriate, the exchange of data), with the aim of minimising the risk of single consignments of fuels being claimed more than once in the Union. Furthermore, the article requires that the EC sets up a Union database (UDB) to enable the tracing of liquid and gaseous transport fuels. In scope are biofuels, RFNBOs, and recycled carbon fuels in the transport sector. Solid biomass fuels are excluded. The UDB is intended to complement the existing certification and traceability requirements for liquid and gaseous transport fuels under the REDII. MSs will require economic operators to enter information inro the database *inter alia* the sustainability characteristics of fuels placed on the market.

Navigant, on behalf of the EC, prepared a scoping study for the UDB in 2020[304], which served as the starting point for the development of the UDB. Finalisation of the UDB concept has been undertaken by the IT team of DG ENER of the EC, based on the options and recommendations outlined in the scoping study complemented by extensive stakeholder engagement with MSs, voluntary schemes, and other stakeholders (such as economic operators, gas DSO/TSOs, and national biomethane registries). The Implementing Regulation 2022/996[305] on certification has further supported the development of the UDB by stipulating legal obligations for economic operators, certification bodies, voluntary schemes, and MSs in accordance with the REDII obligations.

The reporting obligation of the UDB will be the entire supply chain, starting from the (first) gathering point for agricultural or forestry raw material or collection point for wastes and residues up to the point of consumption.[306] For gathering/collecting points, this means that their supplying farms or points of origin will need to be documented in the UDB and all deliveries from these farms and/or points of origin will be entered in the UDB. Similarly, all dependent warehouses and dependent collecting points covered by group certification will need to be recorded so that material can be traced at every location it is stored. During audits, auditors will be required to verify that the information entered into the UDB is accurate and consistent with the audited data.[307]

Pilot testing of the UDB was undertaken by around 20 economic operators during 2022, focussing on liquid fuel supply chains. Following this process, a live version of the UDB was formally launched on 16 January 2023 for the “onboarding” of all voluntary and national schemes and their respective economic operators, MSs, and third-party databases. A phased approach for the onboarding of liquid and gaseous fuels is being applied, with the onboarding of liquid fuels starting first. Onboarding involves the registration of all relevant user information in the UDB. For economic operators, this includes providing information on the certified site (e.g. certificate number, name, and addresses of the sites covered by the certificate, incoming and outgoing materials, estimated production capacity), as well as the active certificate of conformity. A National Trade Register Identifier (NTR ID)[308] is also required to ensure that each economic operator can be uniquely identified to other parties (sellers/buyers). An online Wiki page was launched by the EC in March 2023 to support this process. This provides background information on the UDB, relevant training material, and frequently asked questions.[307]

As of 31 March 2023, six voluntary schemes had commenced the onboarding process and over 6,000 economic operators (equivalent to around 50% of the estimated total) had been added to the UDB. Four MS entities had also provided details for onboarding. Initial stock registration of raw materials and fuels is envisaged to commence once at least 80% of the economic operators have been onboarded. The stocks registered should correspond to the net mass balancing figure of the last mass balance period. After this time, economic operators will be able to register and manage transactions of incoming and outgoing material in the UDB. Transactions will need to be registered within 72 hours of the traded date/shipment and the accompanying Proof of Sustainability (PoS) must be updated before the end of the mass-balance period.

304 https://op.europa.eu/en/publication-detail/-/publication/f9325197-f991-11ea-b44f-01aa75ed71a1/language-en

305 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32022R0996

306 Note that this scope goes further than set out in Article 28(2) of the REDII, which was from their point of production rather further upstream.

307 ISCC. Updates on the Development of the UDB. https://www.iscc-system.org/governance/union-database-udb/essential-information-on-the-union-database/

308 The NTR ID is country-specific and could be a VAT number, business register number, or equivalent.

There are three options available for economic operators to connect with and manage transactions in the UDB:

- Direct exchange in the UDB using the built-in web interface.
- Using a third-party service provider that is connected to the UDB and approved by the voluntary scheme. This provides economic operators with an alternative way to enter transaction data into the UDB without logging into the UDB directly.
- Exchange between the economic operator's own IT System via an "end-point" (access point) operated by either the voluntary scheme or a third-party service provider.

At the time of writing, the ISCC has confirmed that it will act as third-party database service provider, while both 2BSvs and RSB have appointed Bioledger to undertake this role. It is anticipated that additional entities will provide this option in due course.

Ongoing development activities include the integration of existing MS databases (e.g. CarbuRe eINA, Nabisy, REV) with the UDB to avoid double counting of consignments and also importantly, to reduce administrative burden for users. Potential options include bi-directional data flow between both databases or one-directional data flow from the UDB to the MS database.

Once fully operational, the UDB has the potential to improve the robustness and traceability of liquid and gaseous fuel supply chains consumed in the EU, support the MS supervision process, and greatly facilitate cross-border trading of biomethane used in the transport sector.

5. Member State guidance for improved NECPR reporting

All EU-27 MSs have to submit their NECPRs to the Commssion biannually, with their first submission in 2023. MSs can experience difficulties in the reporting requirements and have diverging interpretations of the NECPRs or the underlying requested information. This results in different outcomes regarding the completeness and concistency across the NECPRs of the EU-27 MSs. Based on insights from the previous chapters and the detailed review of the first round of NECPRs as performed in this project, this chapter provides practical guidance, tips, and concrete suggestions to improve reporting. This chapter is organised following the format of the current NECPRs focussing on bioenergy (e.g. the reporting elements within scope of this report). These tangible guidelines and recommendations for MSs on reporting in the areas listed below. Each topic starts with an identification of the areas that seem particularly difficult for MSs to report on. Then, specific recommendations on best reporting approaches and methodologies are provided. This guideline serves as a foundation for bioenergy reporting and can help to improve the overall quality of bioenergy reporting in preparation for the next reporting round in 2025.

5.1. General reflections on terminology and data

Across the different tables in the NECPRs, there are several general recommendations to ensure more transparancy and higher data quality. First of all, it would improve the readability and transparancy of the NECPRs if clear guidance was provided on the units for the various tables. This would encourage NECPR reporting in the same units across all MSs, therefore avoiding potential mistakes and confusion that comes when reporting numerous varying units. These units should be harmonized with the units used in the according sections of the Energy Balances and SHARES for cross-platform comparison and data quality checks.

In the existing system of discussions of all NECPR-related elements, MSs could also receive specific guidance on the more bioenergy-specific reporting elements, potentially with the involvement of bioenergy experts or specific data experts (e.g. Eurostat or SHARES) as to transfer knowledge on the information and background calculations expected for the different fields of the template. This might also strongly improve timely submission, allowing more control and quality checks as well as earlier analysis of the provided information, and may improve consistency on the terminology used across the different NECPRs.

To highlight, the following elements are not included in the template in it's current form, resulting that MSs cannot report on these elements:

- Feedstock used to produce biogas, and biogas demand per sector. This is is especially important with the growing interest in biogas and biomethane after RePowerEU. This would give the EC and the MSs a better overview of EU-27 biogas plans and where they are in their trajectory.
- Projections on bioenergy suppy and demand as part of the MSs' NECPR, specifically on bioenergy topics for pre-determined topics (e.g. bioenergy as a whole, per sector, and per feedstock), years, and units to ensure homogeneity of data for a comparison with the targets set and an accurate assessment of the trajectory the MSs are on.
- Impact of increased demand for biomass on biomass using sectors. This is currently not a reporting requirement for MSs and thus not in the reporting template, but it is a required element of the Union Bioenergy Sustainability Report as per Governance Regulation Annex X point (c) for the Commission.

5.2. Guidelines and support for NECPRs

5.2.1. Current primary supply and demand of biomass by feedstock and and origin

MSs are encouraged to include mandatory reporting elements in NECPR Annex II Table 6 (which considers biomass supply for energy use) and perform data quality checks on the inserted data. Currently, for several data categories the aggregated values do not add up to the sum of the individual types of biomass within that category. It would be highly beneficial if MSs report on all elements within this table. Additionally it was not always 100% clear if units were applied correctly by all MSs. This fragmented data quality makes it challenging to provide a reliable in-depth analysis of this topic.

5.2.2. The share of electricity produced from biomass without the utilisation of heat

In Article 20 (a)(5) of the Governance Regulation this topic of share of electricity produced from biomass without the utilisation of heat is included as example topic for which MSs, where applicable, can include information on long-term and sectoral targets. Although NECPR Annex II Table 7, provides the option to insert a national trajectory or target, the topic of the share of electricity produced from biomass without the utilisation of heat is not explicitly mentioned (while other topics are). MSs are encouraged to report on their electricity produced without the utilisation of heat within this field, additional guidance from the Commission could be beneficial as this topic is not explicitly mentioned.

5.2.3. Energy recovered fom the sludge acquired in the treatment of waste water

Table 7 in Annex II includes a question that considers energy recovered from sludge acquired through the treatment of wastewater. Currently, Table 7 only requests information on topics where MSs have set a national trajectory or target. However, in the NECPRs, only Bulgaria and have reported information on the topic of energy recovered from sludge acquired through the treatment of wastewater. Even so, these two MSs mention that they do not have specific objectives on this topic. Therefore, it could be more insightful to ask all MSs to report information on this topic, similarly to NECPR Annex XVI, Table 7, which requests specific information on the operation of waste-to-energy plants (for all MSs, not only for those who have set national trajectories or targets). In the request, a standard unit should be prescribed (e.g. MWh or ktoe), and potentially a split of the energy in electricity and heat could be added (as optional).

5.2.4. Changes in commodity prices and land use associated with use of biomass and other forms of energy from RES

Currently, the NECPRs ask one, relatively broad, question on the impact of biomass use on commodity prices and one question on land use. These are the questions in Table 2 of Annex XVI: “Please report changes in commodity prices within the MS associated with its increased use of biomass and other forms of energy from renewable sources” and “Please report changes in land use within the MS associated with its increased use of biomass and other forms of energy from renewable sources”.

As described in Section 2.4.1, the relation between biofuel production and commodity prices is complex and a direct quantitative relationship is difficult to be established. At the same time, in qualitative terms, current NECPR responses mainly state that such commodity prices are determined on a global level and that the fraction of such crops that is grown for biomass use purpose are relatively limited. Due to the complex relationship between commodity prices and biomass use, and the inherently global nature of commodity price setting, and in order to improve reporting under this element, i.a. reccomendation to the Mermber states would be to provide, as a minimum, in addition to any additional elements they find necessary, a summary of recent commodity prices within their respecitve MS or of any fluctuations seen in market prices for specific crops produced within a MS. An estimate on whether such fluctuanions could be linked to the use of biomass for energy production, or not, along with a short explanation should also be included.

Regarding the reporting of land use change due to biomass use for renewable energy, MSs were able to report that there was either no land use change, as bioenergy was not based on energy crops, or were able to give an estimation of the amount of land use that is dedicated to energy crops. This field was a qualitative description. However,an analysis would be more useful if the reported data was homogenous by providing more guidance to MSs, such as pre-determined unit per energy crop (current reporting year and data from previous NECPRs, in hectares).

5.2.5. Technological development and deployment of biofuels made from feedstocks listed in Annex IX to Directive 2018/2001

The information provided by MSs on the technological development of Annex IX and deployment of Annex IX biofuels in their NECPRs (Annex XVI, Table 4) is currently inconsistent. Some MSs report on amounts of Annex IX biofuels used in transport, others on production capacities and/or amounts produced, while others only describe recent technological developments in production. Reporting is also done for different time periods and different units are used (TJ, m^3, (k)ton, litres, TWh), as no standard unit is implemented in the mandatory reporting component. It would be beneficial if MSs receive guidance on which unit to report on and which years to include. Even though some suggestions on what to report on are provided in the mandatory reporting element of Table 4, the NECPRs currently allow for a wide range of potential answers as the suggestions are optional and the ‘deployment’ reporting element can be interpreted in various ways. This is illustrated by the wide range of input provided by the MSs. Lastly, the voluntary quantitative reporting element on installed production capacities, number of installations, and actual production has been filled in only by two MSs. The low degree of response to this voluntary table reduces the usability of the data that is provided by these two MSs.

Of all the different input provided in the mandatory reporting element of Annex XVI Table 4, a MS has provided the most comprehensive overview of the amounts of Annex IX biofuels produced in 2021, the amount of Annex IX biogas imported, and an overview of recent technological developments with accompanying technology readiness levels. This can therefore be seen as a reporting example for other MSs in this regard, but could improve its own reporting by adding 2020 data. Most of the MSs that have filled in quantitative data have done so in the mandatory table 4 in the MS template which covers recent development and deployment of Annex IX biofuels. Only two MSs filled in the quantitative table. Some MSs only provide information on the amount of Annex IX biofuels consumed in transport in TJ, whereas others only mention annual production volumes in toe or percentages.

Further streamlining of the Annex IX biofuel development and deployment data inputs from MSs to increase data usability could be achieved by providing more guidance on the two components of the reporting element, as these are not explicit in the reporting template. This guidance could also include the units and reporting periods to ensure more consistency in data. One component could be qualitative in nature and focus on a description of recent technological developments in Annex IX biofuel production, for instance, newly developed production processes or installed biorefineries. For the second component, which is aimed at gathering quantitative inputs on production numbers, the Annex XVI Table 4 reporting element is currently voluntary, however MSs are highly encouraged to report on this element, as it includes relevant reporting categories and standardized units. This would also prevent MSs from reporting on Annex IX biofuel demand instead of production, as the production is already reported on via SHARES in a more comprehensive manner.

5.2.6. Measures taken by Member States for the purpose of ensuring the sustainability of bioenergy

MSs are required to report on measures they have implemented to promote the use of energy from biogas, including the sustainable biomass availability and measures for the sustainability of biomass produced and used, as per Article 20(b)(8) of the Governance Regulation (see Chapter 3). This section reviews the MSs' methods used to report their bioenergy-related measures and provides recommendations on how to improve reporting strategies.

MSs should focus on reporting measures that are active and planned, as these measures are the more relevant. It is not necessary to report measures that have expired, unless the measure has only recently expired or is particularly relevant (i.e., it still has an impact on bioenergy use in the present, for example). However, the relevance and continued impact of the expired measure should be explained, so, in case such expired measure is indeed reported, it should be accompanied by paragraph that includes the relevant explanations. A MS, for example, reports a support scheme measure to promote RES, including biomass heaters in buildings, operational from 2004 until 2013. Since this measure has expired, it is not necessary to continue to report on this measure, unless there are specific reasons for such reporting, which should be explained.

Another MS also reported multiple expired measures; however, each expired measure provides details on the measure that it was replaced by, which are also reported. In such a case, updates and extensions to the expired measures and the progression of measures overtime should be made clear.

Regarding reported bioenergy measures, MSs should provide as many details and as much context as possible. In every case possible, MSs should avoid reporting the broad measure only and instead, provide plentiful detail and clarity. Additionally, qualitative information about the measure, including the sector, feedstock, fuel, and measure type, should be included as often as possible. These reporting strategies ensure proper, efficient, and accurate analysis of each reported measure. For example, a measure reported by a MS is entitled 'Biogas (for transport and process)', but no information is provided as part of the description. Without a description, it is not possible to say what the purpose of the measure is, the type of measure, or the feedstock, nor analysis how helpful this measure could be in terms of incentivizing bioenergy consumption.

Support schemes were also reported in various measures, but it is rather ambiguous how a support scheme incentivizes bioenergy without specific details. Support scheme measures should provide, at the very least, details on the possible recipients or sectors and details on the types of systems and capacities available to receive support under the scheme. A measure reported by a specific MS, for example, provides a support scheme for electricity produced from RES, including biomass/biogas systems with a capacity of 10 kW to 10 MW in commercial and industrial establishments, as well as public buildings. Reporting of support scheme measures could be improved if MSs provide details on how the support can be accessed, especially in cases where the support is available for private homeowners.

Most measures also did not specify the way in which biomass sustainability is ensured; this information is critical and should be reported clearly and explicitly. Some MSs reference REDI or REDII directly, but with no mention of sustainability criteria. For example, a reported measure promotes renewable energy, including biofuels, in the transport sector states that the measure is implemented "in accordance with the transposition of the European directive (REDII and its revision)". Since updated sustainability criteria are included in REDII, it can be assumed that they will be accounted for in the measure, but this should be explicitly stated. Moreover, some older reported measures include REDI sustainability criteria (either directly or as a reference), but it is unclear whether these measures include the additional and updated sustainability criteria from REDII. As an example, a MS reported a measure to support biofuel blending; the measure was implemented in 2000 until 2030. The measure specifies its compliance with REDI, but there are not updates provided noting its compliance with REDII. MSs should be sure to update their reported measures to include mention of REDII sustainability criteria, if applicable. In addition, some MSs report measures that include a reference to 'sustainable biomass', but do not report details on whether this is related to REDII. A best-practice example of how biomass sustainability should be reported is as follows: *This measure introduces the requirements of REDII, including criteria for sustainability and reduction of GHG emissions and complies with the rules on certification*. In this example, sustainability criteria are mentioned clearly alongside the specific EU Directive (in this case, and for the future reporting in 2025 (which will cover the year 2023), REDII is most relevant).

Due to the variety of reporting methods and detail level, analysing and navigating all reported measures was time-consuming and cumbersome. A few recommendations are made below to improve the analysis process and increase the efficiency regarding understanding and navigating the measures. Firstly, many measures were reported that relate broadly to renewable energy. Some measures explicitly list bioenergy as a possible renewable energy source, while other measures did not.[309] For example, in an indirect measure reported by a MS, RES use for production of electricity and heat is promoted, which could include bioenergy, but this is not directly stated. In order to avoid making incorrect assumptions about the intent of reported measures, MSs should be instructed to include specific examples of RES for such measures. Alternatively, a column could be added to the table asking MSs directly whether their reported measure is related to bioenergy. The same reporting. Additionally, MSs could provide an English translation of the reported measures, at the very least, for the measure title. This ensures the measure is translated correctly and with the originally intended meaning and ensures that all bioenergy-related measures are identified if a filter is applied to search for relevant measures.

As a standard practice, a complete, well-reported measure should include the following**: a clear and concise title with reference to the main objective; a description that provides further details on the main objective, explicit mention of the sector(s), feedstock(s), and fuel focus, information on the type of measure, and reference to relevant EU directives, including whether sustainability criteria are considered (or not); implementation status, as well as a period start and finish; and, if necessary, comments or updates on the progress of the measure. When relevant, quantified**

309 Measures related broadly to renewable energy, especially when bioenergy was listed as an example, were often identified as indirect measures.

objectives should be provided with reference dates (i.e., for biofuel blending obligation measures). English translations should also be provided as often as possible, as mentioned above. Measures more broadly related to renewable energy, bioeconomy, etc. should explicitly mention bioenergy, at least as an example, if applicable. To achieve this level of completeness and quality in the measures, clear guidance and instructions must be provided to set the level of expectations for reporting. The example can be used as a reference for MSs.

Name of PaM or group of PaMs
Support for biogas production from manure for electricity generation, heat, and as a vehicle fuel
Short Description
In 2014, the Government introduced a support scheme for biogas production through anaerobic digestion of manure. The support aims to increase biogas production from manure and thereby gain two-fold environmental and climate benefits through reduced methane emissions from manure and the substitution of fossil energy. The increased digestion of manure offers several environmental benefits. It reduces both emissions of greenhouse gases and eutrophication of fresh and marine waters, as well as produces biogas for energy. The biogas generated can be used to generate electricity or heat, or as vehicle fuel. The subsidy amounts to a maximum of xx Euros/kWh of biogas produced.
Relevant Union dimension(s) affected
The PAM is assessed to contribute to mid term and long term national climate goals and therefore contributes to MS x's long-term strategy referred to in Article 15 Regulation (EU) 2018/1999.
Relevant objective(s), target(s) or contribution(s) the policy or measure contributes to
Achieve the national contribution to the 2030 binding Union target for renewable energy as indicated in point (Art. 4(a)(2) of REDII), including sector- and technology-specific measures Art. 20(b)(1) of Governance Regulation; Promotion of the use of energy from biomass Art. 20(b)(8) of Governance Regulation
Sector(s) affected
Electricity, heating, transport
Objectives(s)
Increase biogas production for use in various sectors from manure.
Quantified objective
Production of biogas for electricity generation is xx; for heat is xx; as a vehicle fuel is xx by 2035 Or state "Quantified objectives have not been adopted"
Assessment of the contribution of the policy or measure to the achievement of the Union's climate-neutrality objective set out in Article 2(1) of Regulation 2021/1119 and to the achievement of the long-term strategy referred to in Article 15 Regulation (EU) 2018/1999
Assessment of the contribution of the policy or measure to the achievement of the Union's climate-neutrality objective set out in Article 2(1) of Regulation 2021/1119 and to the achievement of the long-term strategy referred to in Article 15 Regulation (EU) 2018/1999
Union policies which resulted in the implementation of the PaM
Status of implementation
Implemented
Implementation period (Start year; finish year)
2014-2035
Comment on implementation period
Consideration for extension beyond 2035 in 2025
Progress against policy objective
In the latest support period from 1 January 2019 until 31 December 2021, a total amount of xx million Euros was shared among xx biogas plants generating xx GWh. Support for investments in new biogas plants can also be granted through the Sustainable Development Program. New support from 2022 replaces the previous investment support for biogas. Biogas producers can receive support if the biogas is upgraded to a quality that allows input into the distribution network for natural gas or that upgrades biogas to vehicle gas.

Regarding observed cases of fraud in the chain of custody of biofuels, bioliquids, and biomass fuels, all MSs should report something, even if just to say that no cases of fraud were observed. If there are observed cases of fraud to report, as many details should be provided as possible, including relevant dates or timeframes, what the fraud entailed, who was involved, the geographical scale of the observed (or suspected) fraud (whether it was only a domestic issue or involves several MS and/or third countries), what is the impact of the (suspected) fraud, and what is being done in terms of investigation, penalties, and/or rectification.

5.2.7. Estimated impact of the production or use of biofuels, bioliquids and biomass fuels on biodiversity, water resources and availability, soils and air quality

Impacts of production or use of biofuels, bioliquids and biomass fuels on biodiversity, water resources and availability, soils and air quality seem to be a complex reporting element for MSs. The topic itself is broad, covering a range of potential impacts and impacts are sometimes to quantify or generalise making uniform and consistent reporting difficult. However, as the environmental impact is an important reporting topic to continue the assurance of sustainable bioenergy. The majority of MSs do not report any information on the impact of the production of biofuels, bioliquids, and biomass fuels, as reported in Section 4.2.1. Only seven MSs reported information. No MS reported potential impacts or absence of impacts across all categories of biodiversity, air, soil, and water quality. To attain a better understanding of sustainability impacts, countries should report, as a minimum, impacts across all categories, even if merely stating that no impacts are expected or have occurred. Reporting qualitative data can help understand interlinked effects (as described in Section 4) between soil, air, water, and biodiversity. Site specific information is too much detail level for this reporting obligation and too burdensome for a MS. But country-wide qualitative reflections on potential impacts, specific prevention measures or best practices implemented can still be helpful to assess European wide risks of impacts. A limited number of examples of impacts that could occur or where MS could reflect upon are:

- Biodiversity: for example, loss of or endangerment of species in certain agricultural production areas or increased use of management practices promoting biodiversity at farm level (e.g. vegetation buffers next to agricultural areas).
- Air: for example, risks or preventions implemented for nitrous oxide emissions, and methods or limitations/guidelines implemented for manure application
- Water: for example, any perceived relations between water consumption of crops and potential issues with water availability, leakage of agriculture impacting water quality.
- Soil: for example, issues with soil depletion due to specific crops or farming practices, or increased application of crop rotation to reduce soil quality impacts and erosion.
- Any elements specific for biofuel of biomass feedstock production which could highlight potential negative or positive impacts specifically related to bioenergy (e.g., typical crop rotations that the biofuel crops are grown, use of cover / intermediate crops).

Reporting could be further improved by clearly distinguishing the environmental impact of production and cultivation. It is recommended to clarify that impacts related to crop production for bioenergy production are to be reported. For instance, two MS only reported impacts from combustion on air quality and other MS only report on forest production. For the environmental impact of cultivation, the description regarding Table 5 in the Annex should clearly state that environmental impacts of cultivation of biomass and conversion of imported biomass shall be considered. While reporting impacts quantitively is preferred, a qualitative review, like what has been conducted in section 4.2.2 can be reported by MSs. Alternatively, a high-level report of impacts based on MS-specific crop and country combinations, as in Table 18 can be used as a reporting template. Optimally, data should be reported yearly to reflect changes in crop and country combinations used for bioenergy production specific to a MS.

5.2.8. Source and impact on LULUCF sink

The LULUCF criteria as stated in Article 29(7) of Directive (EU) 2018/2001 include three elements: whether MSs are signatories of the Paris Agreement, whether NDCs have been submitted to the UNFCCC, and whether national or sub-national laws have been transposed. Most MSs provide partial information on how biofuels, bioliquids, and biomass fuels produced from biomass meet LULUCF criteria. However, as no MS reported specifically on all three criteria, and the provided level of detail is limited, it seems that the question is not specific to the extent that may be necessary and MS would benefit from aditional guidance.

Only a few MSs provide relatively detailed responses to specific elements of the criteria. Regarding tranposition of laws, for example, two MSs provide responses that confirm they have transposed laws and the practical consequences of such for the LULUCF sector. In relation to the submission of NDCs, France stands out as the MS provides more detail than most, stating that data on emissions and carbon stock have been submitted as well.

To improve future submissions and to generate more in-depth responses, the MS would benefit from a breakdown of the question in Annex II into the three elements that cover the LULUCF criteria. This information could be provided in an additional guidance documents to MSs, to ensure sufficient detailed responses and a higher data quality. As such, MSs would need to provide information on all three criteria descri bed above (a) whether MSs are signatories of the Paris Agreement, b) whether NDCs have been submitted to the UNFCCC, and c) whether national or sub-national laws have been transposed), and the provided information is more complete and consistent over all the MSs. This could include asking MSs what were the specific laws transposed and their practical implications on LULUCF industry players. Also more detail is needed on the origin of the forest biomass, the impact on the LULUCF sinks and how this relates to the MSs' obligation under the LULUCF regulation. To provide more insight into the impact of the forest biomass used for energy, the following aspects should be included: 1) a detailed description of the forest biomass sources that is also consistent with their reporting on biomass supply and 2) an assessment on the implications forest biomass used for energy could have on the LULUCF sink of the given MS. This would provide better insights into activities in each MS, practical implications encountered, and how the criteria are being met. As for the NDC submission element, more guidance could be provided by specificing the question with examples, like 'which emissions are specifically reported?' and to also provide supporting data in the NECPRs themselves.

Annex I: Member State report information concerning changes in commodity prices

Table 23: Information provided in MS NECPRs on changes in commodity prices. Source: MS NECPRs

Member State	Information reported on changes in commodity prices
Austria	No changes identified.
Belgium	No answer
Bulgaria	No answer
Croatia	No answer
Cyprus	No agricultural land is used in Cyprus to produce crops intended for energy purposes. Also, there is no significant use of forest biomass for energy purposes, except from a limited use of timber for heating purposes in households collected directly from consumers. Moreover, the Republic of Cyprus promotes the use of animal, municipal and industrial waste as raw material for biomass energy production, and therefore there has not been, nor is there expected to be in the near future, any significant impact on agriculture or forestry which could lead to a change to the price of raw materials or land use.
Czechia	This is very complex issue, which cannot be fully addressed through this reporting. There have been significant changes in food prices, but these changes were mainly related to the geopolitical situation. There is no available data measuring the price changes for food/feed product due to increased energy use of the same feedstock, but in the expert opinion there were no significant changes due to increased energy use. Price of residues of forest biomass for energy use increased as a reaction to higher prices of energy substitutes (mainly natural gas). But again, there is no readily available statistical data, which can decouple shifts in prices for material products made from waste and residue due to increased energy use and competition for feedstock.
Denmark	No answer
Estonia	The agricultural land used for energy crops is minimal or non-existent in Estonia.
Finland	Until now, there have been no signs of commodity prices or land use significantly changing due to biomass and renewables for energy. For example, the most significant factor in roundwood prices is the demand from forest industry and utilization of agro biomass is negligible in Finland.
France	Biofuels consumed in France are mainly produced from agricultural resources, the price of which is partially dependent on oil, among other factors of tension that can increase prices Also, renewable fuels consume energy for their production (electricity, hydrogen, biomass, etc.) and are therefore dependent on price variations in other sectors. Moreover, the increased use of biomass for various uses may lead to higher biofuel prices. However, hereby some reasons why prices has changed in 2022 : the war in Ukraine disrupted energy markets and some food markets, leading to a sharp rise in commodity prices and price volatility. This volatility influences the price of biofuels, which is particularly dependent on the price of agricultural raw materials, leading to an impact on prices at the pump, as observed on the price of superethanol E85. It was necessary to raise the ceiling of the malus of the incentive mechanism of the tax relating to the use of renewable energies in transport. In June 2022, soaring energy prices also affected biofuels, whose prices peaked.
Germany	No answer
Greece	No answer
Hungary	The price of firewood for 1 m tall oak, typically less than 30 cm in diameter, decreased by 2% between 2019-2020 and 5% between 2020-2021. See deteiled list of forestry product average price list attached.
Ireland	No answer

Italy	Le variazioni dei prezzi delle materie prime in Italia sono ascrivibili come tutte le commodities agricole a diverse esternalità nazionali e internazionali ma le tensioni associate al maggiore utilizzo di biomassa e ad altre forme di energia da fonti rinnovabili sembrano al momento trascurabili. Invece, shock esterni e globali come la pandemia del 2020 e la guerra russo-ucraina del 2022, hanno rappresentato tappe nette nell'oscillazione dei prezzi delle principali commodities agricole, rispetto alla concorrenza tra destinazione energetica e destinazione di trasformazione agricola delle principali commodity bioenergetiche. Le produzioni bioenergetiche si prospettano come un'alternativa alle tradizionali produzioni agroalimentari e contribuiscono a diversificare i canali di mercato di sbocco.
Latvia	The changes in agriculture products are reported by Latvia's Central statistical bureau (https://data.stat.gov.lv/pxweb/lv/OSP_PUB/START__NOZ__LA__LAC/LAC020/table/tableViewLayout1/). The final forest biomass fuels price in final consumption has been stable or reduced for wood pellets and wood briquettes in 2020-2021. Detailed statistical information on forest biomass feedstock prices is available on https://data.stat.gov.lv/pxweb/lv/OSP_PUB/START__NOZ__ME__MEI/MEI020/table/tableViewLayout1/
Lithuania	Support for biofuel production in 2017-2022 provided by the Ministry of Agriculture of the Republic of Lithuania accounts for about 40% of the required funds for the production of biofuels. Average purchase prices of rape seeds in Lithuania in 2020 was 356 EUR per ton, and in 2021 – 480 EUR per ton, triticale (Triticum x secale) seeds – in 2020 was 134 EUR per ton, and in 2021 – 170 EUR per ton. Prices were not influenced by the use of rapeseed or triticale seeds for biofuels, but by the trends of the global grain market, the influence of the Russian invasion of Ukraine on the importance and value of export crops of grain and oil products.
Luxembourg	Market prices for energy plants are not available in Luxembourg. Through the economic accounts, an estimation is calculated of the standard output (€/ha) based on the price of barley and the energy content of the respective crops.
Malta	There is no influence on commodity prices because the support given to PV systems and solar water heaters are provided from the central government's annual budget.
Netherlands	The commodity prices of biomass and wood products in general have risen since the start of the war in Ukraine, due to a combination of the high gas prices and decreased supply.
Poland	Przeciętne ceny skupu kukurydzy [zł/dt] 2020 - 59.9 2021 - 80.26 Przeciętne ceny skupu rzepaku [zł/dt] 2020 - 163.90 2021 - 230.31
Portugal	No answer
Romania	Although the price of biomass for heating purposes has doubled in 2021 (~500 lei per m2) compared to 2020 (~250 lei per m2), the consumption of the biomass is almost at the same level in 2020 and 2021 (taking into account the weather coditions). The increased price of the biomass in this case is as a result of the energy crisis.
Slovakia	Cena kukurice na zrno v roku 2021 vzrástla na 190 eur/t, čo je nárast o 40 % oproti roku 2020. Cena repky olejnej v roku 2021 vzrástla na 440 eur/t, čo je nárast o 20% oproti roku 2020.
Slovenia	No answer

Spain

Changes in the prices of raw materials corresponding to food and forage crops that could be associated with an increase in their use for the production of biofuels at the national level are considered irrelevant.

In relation to the biofuels consumed in Spain in 2021, two types of raw materials can be distinguished:

- Fatty raw materials, used for the production of biodiesel (FAME) and HVO.
- Raw materials for the production of bioethanol.

Food and feed crops: FAME & HVO

In the case of FAME and HVO, first of all, it should be noted that in annual terms there has not been an increase in the joint consumption of these biofuels that use the same type of raw materials compared to 2020. According to data published by the Biofuels Certification Entity (ECB, Ministry for the Ecological Transition and the Demographic Challenge, https://energia.gob.es/biocarburantes/Paginas/estadisticas.aspx), the consumption figures are as follows:

FAME (2020): 1,421,290.19 m3; 1,120,260.93 toe

HVO (2020): 392,394.79 m3; 318,663.81 toe

FAME (2021): 1,321,390.54 m3; 1,041,520.02 toe

HVO (2021): 430,965.32 m3; 349,986.94 toe

2021 vs 2020 Variation

Subtotal FAME+HVO -61,329.12m3 -47,417.78tep

Therefore, the circumstance of increased consumption contemplated in this evaluation does not occur. In addition, according to ECB data, the proportion of raw materials from Spain for these biofuels is very low (11.15% for FAME and 8.04% for HVO) and practically all of it is waste (residual fats and UCOs).

Therefore, the consumption in 2021 of FAME and HVO has not had an impact on the prices of raw materials corresponding to food and forage crops.

food and feed crops: BIOETHANOL:

In the case of bioethanol, the data published by the ECB show a slight increase in consumption:

Bioethanol 2020: 195,422.47 m3 (2020); 98,023.91 toe (2020)

Bioethanol 2021: 248,776.16 m3 (2021); 124,786.12 toe (2021)

2020 vs 2021 Variation: 53,353.69 m3; 26,762.21 toe

According to these same statistics, 36.81% of the bioethanol consumed in 2021 was manufactured with raw materials of national origin. Practically all of this bioethanol was produced with corn (99.31%). Consequently, around 36% of bioethanol production, that is, 89,559 m3, was made with corn grown in Spain. Likewise, it can be considered that of the additional bioethanol compared to 2020 (53,353 m3), 36% was also produced with national corn, that is, 19,207 m3.

Considering a manufacturing yield of 0,417 m3 of bioethanol per ton of corn, the additional volume manufactured with national raw material is translated into a use of 46,060 t of corn grown in Spain.

According to the information published by the Ministry of Agriculture, Fisheries and Food in the Advance for 2021 of the statistics on surfaces and annual crop productions (https://www.mapa.gob.es/es/estadistica/temas/estadisticas-agrarias /agriculture/areas-annual-productions-crops/), the total maize production in Spain in 2021 stood at 4,597,658 t. The corresponding cultivated area amounted to 358,269 hectares.

Therefore, the 46,060 t of national corn associated with the increase in bioethanol consumption in 2021 represent 1% of corn production in Spain.

On the other hand, the total consumption of corn in Spain is much higher than the national production figure, so a large amount is imported to satisfy the demand of all sectors. According to the report The agri-food trade balance in 2021 published by the Ministry of Industry, Commerce and Tourism (https://comercio.gob.es/ImportacionExportacion/Informes_Estadisticas/Paginas/Historico-Balanza.aspx), as regards 130,830 t were exported to corn and 8,357,092 t were imported, resulting in a net import balance of 8,226,262 t.

Consequently, of the total consumption (production + imports - exports), which amounted to 12,823,920 t, the 46,060 t of national corn associated with the increase in bioethanol consumption in 2021 represent 0.36%.

	Taking the above into account, the impact of the increase in bioethanol consumption in 2021 on the price of corn consumed in Spain in that year is considered irrelevant. This evaluation, carried out as explained in the Commission Guide on the increase in energy consumption (biofuels in this case) on an annual basis, can be extended for information purposes only if, in addition to the increase in bioethanol sales in 2021, consumption is analyzed total which, as indicated, stood at 248,776 m3. The national maize used to satisfy this demand would correspond to 36% of it (89,559 m3), that is, 214,770 t. This represents 4.67% of national corn production and 1.67% of total consumption. And if the total bioethanol production of the Spanish plants is considered, it can be seen that, according to the data published by the ECB, it stood at 554,523 m3, since the national market was supplied but a considerable volume was also allocated to the export. Similarly to what was explained above, 36% of said total production (199,628 m3) would correspond to bioethanol manufactured with national corn, which would mean the use of 478,725 t of corn grown in Spain. This figure is equivalent to 10.41% of national corn production and 3,73% of total consumption. The repercussion of these percentages of use of national corn for the production and consumption of bioethanol is insignificant. As a conclusion, it is considered that the prices of maize consumed in Spain have followed the evolution of international markets. FOREST BIOMASS Changes in the prices of raw materials corresponding to forest biomass that could be associated with an increase in its use for energy production at the national level are considered irrelevant. According to the data published by Eurostat (https://ec.europa.eu/eurostat/web/energy/data/shares), solid biomass consumption for energy production in Spain in terms of primary energy in the years 2020 and 2021 were the following: 2020 2021 Variation Biomass energy (toe) 7,168,850.39(2020) 7,439,247.59 (2021) 270,397.20(VARIATION 2021 VS 2020) The increase in 2021 with respect to consumption in 2020 represents a variation of 3.77%. This percentage is not considered to have an impact on changes in the prices of these raw materials. In addition, it must be taken into account that the extraction rate in Spain is very low, as indicated in the 2020 Forest Statistics Yearbook (https://www.miteco.gob.es/es/biodiversidad/estadisticas/forestal_anuarios_todos. aspx), which is the latest available. According to the information contained in said report, the annual growth of timber volume stood at 47,039,106 m3 and the volume of firewood at 118,825,302 m3. And, as stated in the same yearbook, the total number of cuts amounted to 15,936,844 m3 (33.88% over annual growth) and the use of firewood to 1,450,342 m3 (1.22% over the total volume). Therefore, it is considered that the energy use of part of this forest biomass does not give rise to significant changes in its price.
Sweden	The current energy situation and the status of the various commodity markets sets for various points in time how the correlation in the markets is functioning, High demand of energy assortments might from time to time increase prices of traditional assortments. On the other hand production of energy assortments generally increase profitability of forest operations and this way decreases prices of tradtional assortments. National prices of roundwood are presented in https://www.skogsstyrelsen.se/statistik/statistik-efter-amne/rundvirkespriser/

Annex II: Current (semi-)commercial scale production technologies for Annex IX biofuels

In this section, a description is provided for each of the different techniques that are currently applied in one of the biorefineries, or at least on a demonstration plant scale, discussed in Section 2.5. Most of the information is based on the JRC's 2022 advanced biofuels and bioenergy reports[310, 311], which provide a more in-depth description of the different technologies included, among others.

Hydrotreated Vegetable Oil (HVO)

Hydrotreated Vegetable Oil (HVO), sometimes also known as Hydroprocessed Esters and Fatty Acids (HEFA) drop-in biofuel, is produced via a process called hydroprocessing or hydrotreating, as implied by its name.[312] HVO can be produced from (non-) Annex IX oils, fats, and pyrolysis oil (also known as bio-oil), an intermediary product from which various end products can be made. Pyrolysis is the thermochemical conversion of solid biomass into bio-oil, different gases (hydrogen, methane, carbon monoxide, and carbon dioxide), and solid biochar in the absence of oxygen at temperatures between 450 °C and 600 °C. Pyrolysis can be sped up by employing catalysts, which also results in bio-oil of higher quality.

Hydroprocessing involves various techniques including hydrotreating to remove impurities in the form of sulphur, oxygen, and nitrogen, followed by catalytic hydrogenation to add hydrogen to the initially unsaturated lipid fractions and break them up into smaller molecules such as propane and free fatty acids. Oxygen is then removed from these fatty acids via hydrodeoxygenation (HDO), decarboxylation, or decarbonylation, depending on the specific product the HVO is eventually turned into (jet fuel, maritime fuel, etc.). This also determines which processes the HVO undergoes further downstream.

Gasification

In this process, a feedstock is partially oxidized at high temperatures (700-1500 °C) in the presence of a gasifying agent such as air, oxygen, or steam without combustion taking place. It can occur at a wide range of operating conditions, and different types of reactor technologies are available. The resulting product is raw syngas, a mixture of carbon monoxide (CO) and hydrogen (H_2), as well as impurities such as methane (CH_4), carbon dioxide (CO_2), hydrogen sulphide (H_2S), ammonia (NH_3), hydrogen cyanide (HCN), particulates, higher condensable hydrocarbons, and other pollutants. The syngas is then purified, for which a wide range of technologies is available that can be categorised into primary and secondary measures. The former includes modification of the gasifier design, adjustment of the operating conditions and use of catalysts and additives. The latter involves physical processes (use of filters, cyclones, electrostatic precipitators, scrubbers) and thermal-catalytic processes (cracking, oxidation catalytic reforming, plasma processes).

Biomethanol

Biomethanol is produced either directly from biomass or from pyrolysis oil. If needed, pyrolysis oil can be upgraded as a first step using techniques such as solvent extraction,

310 Joint Research Centre. (2022). ADVANCED BIOFUELS IN THE EUROPEAN UNION. https://publications.jrc.ec.europa.eu/repository/handle/JRC130727.
311 Joint research Centre (2022), BIOENERGY IN THE EUROPEAN UNION, JRC Publications Repository - Clean Energy Technology Observatory: Bioenergy in the European Union – 2022 Status Report on Technology Development, Trends, Value Chains and Markets (europa.eu)
312 BIKE. (2021). D 3.1 Overview on biofuels production facilities and technologies in Europe. https://www.bike-biofuels.eu/wp-content/uploads/2021/09/20210914_BIKE_D3.1_4.0_REC.pdf.

emulsion, and the same hydroprocessing techniques used for HVO production (hydrocracking, hydrotreatment, and hydrodeoxygenation).

The next step in biomethanol production is the gasification of either biomass or pyrolysis oil. The resulting gas is conditioned to optimize its quality for catalytic synthesis, for instance by optimizing the H_2:CO ratio, as the initial H_2O concentration is often too low to produce biomethanol. A ratio of two H_2 to one CO is ideal for biomethanol production and can be achieved by a Water Gas Shift reaction. This converts CO and H_2O into CO_2 and H_2. CO_2 removal might be needed afterwards.

Syngas is then converted into biomethanol via a catalytic process based on copper oxide, zinc oxide, or chromium oxide catalysts. Lastly, the product is distilled to remove water generated during methanol synthesis.

Bioethanol

Bioethanol production from cellulosic material is considered one of the most promising methods for advanced ethanol production. A wide range of lignocellulosic materials can be used as feedstocks for this process, including several specified in Annex IX Part A (such as straw and cobs cleaned of kernels of corn). To separate cellulose and hemi-cellulose from the lignin the raw material first undergoes pre-treatment. The lignin can later be used as a fuel for electricity generation to drive the process. Enzymatic hydrolysis is then used to break down the polysaccharides into their C6 and C5 monosaccharide building blocks (which is also known as saccharification). These sugars are fermented into alcohols using common yeasts for C6 sugars or genetically modified yeasts for C5 sugars. Of those, the C6 fermentation process is not as well developed as the C5 process. Typical alcohol end products are ethanol and different forms of butanol. Genetic modification of yeasts can be used to tweak which exact alcohols are produced. Although fermentation of lignocellulosic biomass to ethanol is increasingly being applied on a commercial scale, considerable challenges remain to further improve this method. These include the development of pre-treatment methods with increased efficiency, more efficient enzymes and improving the effectiveness of yeasts that can convert C5 sugars.

Bioethanol, as well as other bioalcohols, can also be produced via fermentation of syngas through microorganisms. This gas-based bioconversion pathway has considerable advantages over the sugar fermentation pathway discussed before, as it takes place under mild conditions of temperature and pressure and can also utilize lignin and carbohydrate fractions of biomass. The alcohols produced via this method can be refined further into other fuels such as Sustainable Aviation Fuels (SAF).

Biomethane

Biomethane can be produced via anaerobic digestion of biomass by microorganisms and the upgrading of the resulting biogas. This initial biogas can be produced via different anaerobic digestion processes depending on the operating temperature. The types of feedstocks that can be used are varied and include wet biomass and organic waste, such as agricultural, organic residues and wastes, sewage sludge, animal fats and slaughtering residues, sewage sludge from wastewater treatment, and aqueous biomass (micro and macro algae). Feedstocks can also be combined to optimize the carbon to nitrogen (C/N) ratio and therefore optimize yield. The biogas produced is a mixture of methane (typically 50-70%), carbon dioxide (30-40%), and other gases such as hydrogen, nitrogen, hydrogen sulphide, ammonia, and trace amounts of carbohydrates and organic silicon compounds. The biogas is then upgraded to methane using carbon dioxide removal techniques such as Pressured Water Scrubbing (PWS), Pressure Swing Absorption (PSA), and various forms of absorption and separation.

Another promising production route, although not yet commercially viable, involves a biological conversion of syngas to biomethane (biomethanation). In this method, microorganisms metabolize syngas into methane in bioreactors operated at mild temperatures and pressures. Metabolization can occur via different anaerobic biological routes. Microorganisms that can be utilized for this include methanogenic archaea, acetogenic bacteria, and hydrogenogenic bacteria, among others. However, there are still challenges to be overcome before this method can be applied at commercial scale, including the limited mass transfer rate of H_2 and CO due to their low solubility in a liquid medium and the low cell growth rate of the microorganisms.

Fischer-Tropsch fuels

In Fischer-Tropsch (FT) synthesis CO and H_2 react under high atmospheric pressure (10 to 40 bar) in the presence of a catalyst to form a variety of different hydrocarbons. Syngas is used as feedstock, which can be produced from gasification of biomass, as discussed before. Again, realizing the proper H_2/CO ratio is crucial the get the desired end products. The type of catalyst and process temperature used also influence the variety of produced hydrocarbons. Upgrading of final products is required to get to useable fuels such as biomethanol, renewable diesel, or SAF. This can, for instance, be achieved via hydroprocessing or distillation. Although FT synthesis has been applied on an industrial scale for decades with fossil feedstocks, there are still some challenges to be overcome in its large-scale application for biomass processing related to adequate feedstock supply logistics.

Annex III: Tables per Member State with an overview of measures related to promoting the use of energy from biomass and respecting the sustainability criteria and GHG saving criteria

Table 24: Overview of bioenergy measures for Austria

Measure Name	Main Objective(s)	Sector Focus	Feedstock Focus	Fuel Focus	Measure Type	Implementation Timeframe	Way in which Sustainability of Biomass is Ensured
Increase the share of renewable energy in electricity supply and district heating	Promote end use	Electricity	-	Solid biomass, biogas	Obligation, OPEX subsidy	Start: 2002	-
Increase the share of clean energy sources in road transport	Promote end use	Transport	-	Biofuels	Obligation	Start: 2004	Continuation of Directive 2009/28/EC, which includes biomass sustainability criteria
Indirect Measure(s)							
Domestic Environmental Support Scheme	Promote end use	Energy, Industry, Manufacturing	-	Solid biomass	Support scheme	Start: 1993	-

Table 25: Overview of bioenergy measures for Belgium

Measure Name	Main Objective(s)	Sector Focus	Feedstock Focus	Fuel Focus	Measure Type	Implementation Timeframe	Way in which Sustainability of Biomass is Ensured
Promoting renewable energy in the transport	Promote end use	Transport	-	Biofuels	Obligation, Regulatory/legislative change	2004-2030	In accordance with the transposition of the European Directive (REDII and its revision)
Biomass energy strategy	Promote end use	Energy	-	Solid biomass	Strategy	Start: 2016	-
Biomass flows management	Promote end use	Energy	-	Bioliquids	Regulatory/legislative change	Start: 2010	Transposition of the Directive 2009/28/EC concerning the sustainability criteria for bioliquids and biofuels
Biomethanisation	Promote end use, Stimulate production of fuels	-	Wastes	Biogas	-	Start: 2024	-

Biomethanisation strategy	Promote end use, Stimulate production of fuels	-	Agricultural biomass, Wastes	Biogas	Strategy	-	-
Energy taxation on fossil fuel for energy production	Promote end use	Electricity	-	Solid biomass	Tax incentive	Start: 2004	-
Reinforced calls green heat- residual heat and sustainable heat networks	Promote end use	Heating	-	Biomethane	Support scheme	-	-
Renewal of individual biomass heating systems	Promote end use	Building, Heating	Forest biomass	Solid biomass	Financial incentive	2019-2019	-
Building infrastructure for cleaner fuels	Promote end use	-	-	Biogas	Strategy	2022-2026	-
Indirect Measure(s)							
Flemish Agricultural Investment Fund (VLIF)	Promote end use	Agriculture	-	-	Support scheme	-	Sustainable and local biomass use
Standardization tires and fuels.	Promote end use, Stimulate production of fuels	Transport	-	-	Regulatory/legislative change	2019-2021	-
Optimization of the use of industrial and commercial activity zones to be provided for in the new marine development plan	Energy security, Stimulate availability of feedstocks	-	Agricultural biomass	Biofuels	Strategy	2023-2024	-

Table 26: Overview of bioenergy measures for Bulgaria

Measure Name	Main Objective(s)	Sector Focus	Feedstock Focus	Fuel Focus	Measure Type	Implementation Timeframe	Way in which Sustainability of Biomass is Ensured

New requirements for the determination of the consumed quantities of fuels and energy from renewable sources consumed in the transport sector	Promote end use	Transport	-	Biofuels	Obligation, Regulatory/legislative change	Start: 2019	Based on implementation of Directive 2015/1513 and REDI, which include biomass sustainability criteria and ILUC
Amendment to the Ordinance on the sustainability criteria for biofuels and bioliquids	Safeguard sustainability	Transport	-	Biofuels, Bioliquids	Obligation, Regulatory/legislative change	Start: 2019	Regulation defines the sustainability criteria for biofuels and liquid biomass fuels for transport
Methodology for calculating greenhouse gas emissions from the whole life cycle of biofuels and liquid fuels from biomass taking into account indirect changes in land use	Safeguard sustainability	Transport	-	Biofuels, Bioliquids	Regulatory/legislative change	Start: 2019	Methodology shall be amended following the adoption of the Law on Amendments and Supplements to the Energy from Renewable Sources Act, which introduces the requirements of Directive (EU) 2018/2001, including criteria for sustainability and reduction of GHG emissions

Table 27: Overview of bioenergy measures for Cyprus

Measure Name	Main Objective(s)	Sector Focus	Feedstock Focus	Fuel Focus	Measure Type	Implementation Timeframe	Way in which Sustainability of Biomass is Ensured
Support scheme for the installation of renewable energy sources (RES) systems that will operate in the competitive electricity market	Stimulate production of fuels, Promote end use	Electricity	-	Biogas, Solid biomass	Support scheme	2016-2018	-

Certification of small-scale RES system installers	Promote end use	Heating	-	Solid biomass	Certificate, Strategy	Start: 2015	-
Support scheme for the promotion of renewable energy sources and energy saving	Promote end use	Heating	-	Solid biomass	Support scheme	2004-2013	-
Replacement of the conventional transport fuels with biofuels	Promote end use	Transport	-	Biofuels	Obligation	Start: 2011	Biofuels used to meet mixing obligation must meet sustainability criteria
Support scheme for the production of electricity from renewable energy sources for own use Category Self-consumption	Promote end use	Electricity	-	Biogas, Solid biomass	Support scheme	2013-2018	-
Waste (National Municipal Waste Management Strategy)	Reduce landfill, Stimulate production of fuels	Electricity, Heating	Wastes	Biogas	Strategy	Start: 2024	-

Table 28: Overview of bioenergy measures for Czechia

Measure Name	Main Objective(s)	Sector Focus	Feedstock Focus	Fuel Focus	Measure Type	Implementation Timeframe	Way in which Sustainability of Biomass is Ensured
Support of biofuels	Promote end use	Transport	-	Biofuels	Obligation, Tax incentive	2000-2030	Measure is in compliance with Directive 2009/28/EC, therefore includes biomass sustainability criteria
Economic and tax tools for road vehicles	Promote end use	Transport	-	Biofuels	Tax incentive	2021-2030	-
Action Plan for biomass in the Czech Republic	Promote end use	Energy	-	Solid biomass	Strategy	2012-2020	-

Indirect Measure(s)							
Preferential feed-in tariffs for electricity produced from renewable energy sources	Promote end use, Safeguard sustainability	Electricity	-	-	OPEX subsidy	2004-2035	Amendments made, which now include the biomass sustainability criteria
Operational Programme Environment 2014 - 2020	Promote end use	Heating	-	Solid biomass	CAPEX subsidy, Strategy	2014-2020	-

Table 29: Overview of bioenergy measures for Germany

Measure Name	Main Objective(s)	Sector Focus	Feedstock Focus	Fuel Focus	Measure Type	Implementation Timeframe	Way in which Sustainability of Biomass is Ensured
Federal Programme for funding for measures for increasing energy efficiency in agriculture and horticulture	Promote end use	Agriculture	-	Biogas	Strategy	Start: 2016	-
GHG quota (including support program for advanced biofuels and electricity-based fuels). (Transport)	-	Transport	-	Biofuels	Regulatory/legislative change, Strategy	2020-2035	-
Renewable Energy Act (Electricity sector / energy industry)	Promote end use	Electricity, Energy	-	Solid biomass	OPEX subsidy, Tenders	Start: 2000	-
Climate-neutral federal administration	Promote end use	Transport	-	Biogas	Strategy	Start: 2021	-

Table 30: Overview of bioenergy measures for Denmark

Measure Name	Main Objective(s)	Sector Focus	Feedstock Focus	Fuel Focus	Measure Type	Implementation Timeframe	Way in which Sustainability of Biomass is Ensured

7-AG-19: Biogas (for transport and process)	-	Transport, Manufacturing	-	Biogas	-	2021-2023	-
7-AG-20: Subsidy for upgrading and purification of biogas	Stimulate production of fuels	-	-	Biogas	CAPEX subsidy	2018-2023	-
7-AG-21: Subsidy schemes regarding biogas plant	-	-	-	Biogas	CAPEX subsidy	2022-2023	-
2-EN-02: Biomass Agreement (Agreement on the use of biomass in electricity production)	Promote end use	Electricity	Forest biomass (straw, wood pellets, wood chips), Wastes	Biogas, Solid biomass, Bioliquids (animal and vegetable oils, biodiesel, bioethanol)	Regulatory/legislative change	1993-2050	-
2-EN-03: Price supplement and subsidies for renewable energy production	Promote end use	Energy	-	-	CAPEX subsidy, Tenders	2008-2050	-
4-TR-08 (expired and replaced by 4-TR-18): EU requirements regarding biofuels	Promote end use	Transport	-	Biofuels	Obligation	2012-2050	Biofuels must live up to EU sustainability criteria
4-TR-18 (expired and replaced by 4-TR-24): Increased blend in requirements for biofuels in petrol, diesel and gas from 5.75% to 7.6% (enhancement of 4-TR-08)	Promote end use	Transport	-	Biofuels	Obligation	2020-2050	Biofuels must live up to EU sustainability criteria
4-TR-24: Maintaining the increased blend in requirement (extension of 4-TR-18)	Promote end use	Transport	-	Biofuels	Obligation	2021-2050	Biofuels must live up to EU sustainability criteria

7-AG-06: Biogas plants	Promote end use	Energy, Heating, Industry, Transport	-	Biogas	CAPEX subsidy, Regulatory/legislative change	1987-2050	-
7-AG-09 (expired): Agreement on Green Growth	Promote end use, Stimulate production of fuels	Agriculture	-	Biogas	Regulatory/legislative change	2009-2015	-
7-AG-15: Pool for the promotion of biogas and other green gases by tender	Promote end use, Stimulate production of fuels	-	-	Biogas	Tenders, Regulatory/legislative change	2021-2050	-
Indirect Measure(s)							
7-AG-11(expired): Agreement on Green Growth 2.0	Stimulate production of fuels	-	-	-	Regulatory/legislative change	2010-2015	-
3-BU-08: Renewables for the industry	Promote end use	Manufacturing	-	Biogas, Solid biomass	CAPEX subsidy	2013-2023	-

Table 31: Overview of bioenergy measures for Estonia

Measure Name	Main Objective(s)	Sector Focus	Feedstock Focus	Fuel Focus	Measure Type	Implementation Timeframe	Way in which Sustainability of Biomass is Ensured
Support for renewable and efficient CHP based electricity production	Promote end use	Electricity	Agricultural biomass, Forest biomass, Wastes	-	CAPEX subsidy	Start: 2007	-
Encouraging the introduction of biomethane	Promote end use	Transport	-	Biomethane	Strategy	2021-2027	-
Increasing the share of biofuels in transport	Promote end use	Transport	-	Biofuels, Biomethane	Obligation	2010-2025	-
Promoting the use of biomethane in heavy duty vehicles	Promote end use	Transport	-	Biomethane	Support scheme	Start: 2036	-

Promoting the use of biomethane in busses	Promote end use	Transport	-	Biomethane	Financial incentive	2014-2020	-
Investments into improved performance of agricultural holdings	Stimulate production of fuels, Promote end use	Agriculture, Energy	Agricultural biomass (manure or crop residues), Residues	-	CAPEX subsidy	2015-2023	-
Oil boiler replacement programme	Promote end use	Building, Heating	-	Solid biomass	Financial incentive	Start: 2014	-
Indirect Measure(s)							
Investments in exploitation of bioresources	Energy security, Support innovation	Energy	-	-	CAPEX subsidy	2023-2027	-

Table 32: Overview of bioenergy measures for Greece

Measure Name	Main Objective(s)	Sector Focus	Feedstock Focus	Fuel Focus	Measure Type	Implementation Timeframe	Way in which Sustainability of Biomass is Ensured
Recovery of biogas	Promote end use, Stimulate production of fuels	Energy	Wastes	Biogas	-	Start: 2002	-
Promotion of innovative technologies in transport	Support innovation, Stimulate production of fuels	Transport	-	Biofuels, Biogas	Strategy	2016-2030	"Development of liquid and gaseous biofuels…from sustainable biomass"
Use of tax incentives to promote alternative fuels in transport (biofuels, hybrid fuels, electric fuels, natural gas, LPG)	Promote end use	Transport	-	Biofuels	Regulatory/legislative change, Tax incentive	Start: 2020	-
Biofuel use in transportation	Promote end use	Transport	-	Biofuels	Obligation, Tax incentive	Start: 2005	-

Indirect Measure(s)							
Recovery of organic waste	Reduce landfill	-	-		Strategy	Start: 2002	-
Development of innovative decarbonisation technologies, as well as applications for carbon capture, storage and utilisation	Support innovation, Stimulate production of fuels	Electricity, Heating	-	Solid biomass, Bioliquids, Biogas	Strategy	2016-2030	“Development, demonstration and scale-up of solid, liquid and gaseous bioenergy intermediates through biochemistry / thermochemistry / chemical conversion from sustainable biomass"

Table 33: Overview of bioenergy measures for Spain

Measure Name	Main Objective(s)	Sector Focus	Feedstock Focus	Fuel Focus	Measure Type	Implementation Timeframe	Way in which Sustainability of Biomass is Ensured
Royal Decree 205/2021, of March 30, which modifies Royal Decree 1085/2015, of December 4, on the promotion of biofuels, and regulates the targets of sale or consumption of biofuels for the years 2021 and 2022	Promote end use	-	-	Biofuels	-	2021-2022	-
Aid program for the execution of thermal biomass projects in buildings. BIOMCASA	Promote end use	Heating	-	-	Strategy, Support scheme	2009-2020	-
Biofuels quota obligation	Promote end use	Transport	-	Biofuels	Obligation	2009-2030	Biofuels have to comply with RED sustainability and carbon footprint requirements

Hoja de Ruta del Biogás (Biogas Roadmap)	Promote end use, Stimulate availability of feedstocks	Energy, Transport	Wastes, Agricultural biomass	Biogas, Biomethane	Strategy, Support scheme	2022-2030	Mention of guarantee of origin
Order TED/706/2022, of July 21, approving the regulatory bases and incentive programs for the granting of aid to singular projects of biogas facilities, within the framework of the Recovery, Transformation and Resilience Plan	Promote end use, Stimulate production of fuels	Electricity, Heating	-	Biogas	Regulatory/legislative change, Support scheme	Start: 2021	-
Introduction of advanced biofuels in air transport	Promote end use, Stimulate production of fuels	Transport	Agricultural biomass, Annex IX	Biofuels	Regulatory/legislative change	2021-2030	-
Sistema de garantías de origen para gases renovables (Guarantee of origin system for renewable gases)	Safeguard sustainability	-	-	Biogas, Biomethane	Certificate	Start: 2023	Guarantees of origin for renewable gases
Medidas con impacto en el transporte marítimo (Measures with an impact on maritime transport)	Promote end use, Stimulate production of fuels	Transport	-	Biofuels	Regulatory/legislative change	-	-
Introduction of advanced biofuels in maritime transport	Promote end use, Stimulate production of fuels	Transport	-	Biofuels	Regulatory/legislative change	Start: 2021	-

Promotion of renewable gases in the residential sector	Promote end use	Electricity, Energy, Heating, Building	-	Biogas, Biomethane	Regulatory/legislative change	2021-2030	Efficient use of renewable gases, supported by a certification system and determination of a system of guarantees of origin of renewable gases that accredits their origin and traceability and environmental impact associated with their production and use
Incentive program 6 "Implementation of renewable energy installations thermal in the residential sector" (Royal Decree 477/2021), linked to self-consumption and storage, with sources of renewable energy, as well as the implementation of renewable thermal systems in the residential sector	Promote end use	Building, Heating	-	Solid biomass	Financial incentive, Strategy	2021-2023	-
Specific programs for the use of biomass (NECP Measure 1.11)	Promote end use	Electricity, Heating	Agricultural biomass, Forest biomass, Residues	Solid biomass	Regulatory/legislative change	-	Promotion of energy from biomass with sustainability criteria and promotion of certification and the principle of proximity of origin in the use of biomass

Real Decreto 235/2018, método de cálculo de las emisiones de gases de efecto invernadero para suministradores de combustibles, sistema de verificación de la sostenibilidad y objetivo indicativo en biocombustibles avanzados (Royal Decree 235/2018, method of calculating greenhouse gas emissions for fuel suppliers, sustainability verification system and indicative target for advanced biofuels)	Safeguard sustainability	-	-	Biofuels	Certificate, Regulatory/legislative change	Start: 2018	Sustainability verification system
Incorporation of renewables in the industrial sector (NECP Measure 1.5)	Promote end use	Industry	-	Biogas, Solid biomass	Regulatory/legislative change	-	-
Establecimiento de objetivos de venta y consumo de biocarburantes en 2021 y 2022 (Establishment of sales and consumption targets for biofuels in 2021 and 2022)	Promote end use	Transport	-	Biofuels	Regulatory/legislative change	2021-2022	-

Resolución de 18 de julio de 2022, de la Secretaría de Estado de Energía, por la que se convoca la tercera subasta para el otorgamiento del régimen económico de energías renovables al amparo de lo dispuesto en la Orden TED/1161/2020, de 4 de diciembre. (Resolution of July 18, 2022, of the Secretary of State for Energy, by which the third auction is called for the granting of the economic regime of renewable energies under the provisions of Order TED/1161/2020, of 4 December.)	Promote end use	Electricity	-	Solid biomass	Tenders	2022-2047	-
Resolution of March 11, 2019, of the Secretary of State for Energy, by which biopropnane is included in the Annex to Order ITC/2877/2008, of October 9, which establishes the mechanism for promoting use of biofuels and other renewable fuels for transport purposes	Promote end use	Transport	-	Biofuels (biopropane)	Regulatory/legislative change	Start: 2019	-

Circular 5/2020, of July 9, of the National Markets and Competition Commission, which regulates the management of the mechanism to promote the use of biofuels and other renewable fuels for transport purposes and modifies Circular 2 /2017, of February 8, which regulates the procedures for the constitution, management and distribution of the compensatory payment fund of the mechanism to promote the use of biofuels and other renewable fuels for transport purposes.	Promote end use	Transport	-	Biofuels	Financial incentive	Start: 2020	-
Resolution of the National Markets and Competition Commission, 17 September 2020, determining the raw materials used in the production of biofuels for the purposes of fulfilling the sale or consumption objectives of biofuels for transport	Stimulate availability of feedstocks, Stimulate production of fuels	Transport	-	Biofuels	Regulatory/legislative change	Start: 2020	-

I Programa Nacional de Control de la Contaminación Atmosférica: T.1 Reducción de las emisiones para el transporte por carretera, ferrocarril, aviación y marítimo (I National Air Pollution Control Program: T.1 Reduction of emissions for road, rail, aviation and maritime transport)	Promote end use	Transport	-	Biofuels	Strategy	2019-2022	-
Indirect Measure(s)							
Aid program for carrying out energy efficiency actions on farming facilities/installations	Promote end use	Agriculture, Industry	-	Solid biomass	Obligation, Support scheme	Start: 2021	-
Promoción de gases renovables en el sector industria (Promotion of renewable gases in the industrial sector)	Promote end use	Industry	-	Biomethane	Regulatory/legislative change	2021-2030	-
Fomento de la reducción de emisiones en el sector de los residuos. (Medida 1.22 del PNIEC) (Promotion of the reduction of emissions in the waste sector. (Measure 1.22 of the PNIEC))	Promote end use, Reduce landfill, Stimulate availability of feedstocks, Stimulate production of fuels	Waste	Wastes	Biogas	Regulatory/legislative change	-	-

Promoción de gases renovables (Medida PNIEC 1.8) (Promotion of renewable gases (PNIEC Measure 1.8))	Promote end use	-	-	Biomethane	Regulatory/legislative change	-	-
Medidas en el transporte por Carretera (Measures in road transport)	Promote end use	Transport	-	Biofuels	Regulatory/legislative change	-	-
Medidas transporte por ferrocarril (Rail transport measures)	Promote end use	Transport	-	Biofuels	Regulatory/legislative change		-
Aid program for the execution of large thermal facilities that use renewable sources in buildings and industry. GIT	Promote end use	Building, Industry	-	-	Support scheme	2011-2020	-
Fomento de las absorciones en sumideros naturales (Medidas 1.24 y 1.25 del PNIEC, sumideros forestales y agrícolas respectivamente) (Promotion of absorption in natural sinks (Measures 1.24 and 1.25 of the PNIEC, forest and agricultural sinks respectively))	Stimulate availability of feedstocks	Agriculture, Forestry	Forest biomass	-	Regulatory/legislative change	-	-
Estrategia Forestal Española horizonte 2050 y Plan Forestal Español 2022-2032 (Spanish Forest Strategy horizon 2050 and Spanish Forest Plan 2022-2032)	Stimulate availability of feedstocks	Agriculture, Forestry	Forest biomass	-	Strategy	2022-2032	-

PAREER-CRECE Program (Aid Program for Energy Rehabilitation in Buildings in the Household and Hotel Sectors)	Promote end use	Building, Energy	-	Solid biomass	Support scheme	2013-2018	-
Technological renovation plan in existing electricity generation projects with renewable energies (Medida PNIEC 1.9)	Support innovation	Electricity	-	Biogas, Solid biomass	Regulatory/legislative change	-	-
Medidas energéticas en el sector residencial (Energy measures in the residential sector)	Promote end use	Building, Energy	-	Biogas	Regulatory/legislative change	-	-

Table 34: Overview of bioenergy measures for Finland

Measure Name	Main Objective(s)	Sector Focus	Feedstock Focus	Fuel Focus	Measure Type	Implementation Timeframe	Way in which Sustainability of Biomass is Ensured
Biofuel distribution obligation 100 per cent in 2045	Promote end use	Transport	-	Biofuels	Obligation	2030-2045	-
Increasing the number of wood fuel terminals	Energy security, Stimulate production of fuels	Energy	Forest biomass	Solid biomass	-	-	-
Promoting the use of bioliquids in machinery	Promote end use	Machinery	-	Bioliquids	Obligation	-	-
Promoting the use of bioliquids in heating of buildings	Promote end use	Building, Heating	-	Bioliquids	Obligation	Start: 2019	-

Improving energy efficiency and promoting the use of alternative fuels in machinery	Promote end use	Machinery	-	Biogas	-	-	-
Promoting biogas in electricity and heat production	Promote end use	Electricity, Heating	Forest biomass, Wastes	Biogas	CAPEX subsidy, OPEX subsidy, Tax incentive	Start: 1997	-
Promoting the use of biogas	Promote end use	Agriculture	-	Biogas	-	-	-
Support for charging stations and biogas and hydrogen filling stations in road traffic (auction)	Promote end use	Transport	-	Biogas	Tenders	Start: 2018	-
Promoting the use of biofuels in the transport sector, amending minimum levels	Promote end use	Transport	-	Biofuels	Obligation	Start: 2020	-
Inclusion of biogas and electrofuels in the distribution obligation legislation	Promote end use	Transport	-	Biogas	Obligation	-	-
Indirect Measure(s)							
Promoting the use of renewable fuels in the transport sector	Promote end use	Transport	-	Biofuels	Obligation	Start: 2008	-

Table 35: Overview of bioenergy measures for France

Measure Name	Main Objective(s)	Sector Focus	Feedstock Focus	Fuel Focus	Measure Type	Implementation Timeframe	Way in which Sustainability of Biomass is Ensured

La programmation pluriannuelle de l'énergie 2 (2019-2023 ; 2024-2028) (Multiannual energy programming 2 (2019-2023; 2024-2028))	Promote end use	Energy	-	Biogas	Strategy	2019-2028	-
Dispositif de suramortissement pour l'achat de véhicules lourds plus propres (Additional bonus for the purchase of cleaner heavy-duty vehicles)	Promote end use	Transport	-	Biomethane	Financial incentive	Start: 2016	-
Plan Energie Méthanisation Autonomie Azote (Energy Methanization Nitrogen Autonomy Plan)	Energy security, Stimulate production of fuels	Electricity, Energy	Wastes	Biogas, Biomethane	Strategy	Start: 2013	-
"MOFOB / CARTOFOB (Formerly National Observatory of Biomass Resources)	Stimulate availability of feedstocks	-	Forest biomass	-	-	Start: 2015	-
Mesures de promotion du gaz renouvelable (Renewable gas promotion measures)	Promote end use, Stimulate production of fuels	Energy, Transport	-	Biogas, Biomethane	Tenders	2019-2028	-

Mesures pour développer les biocarburants (Measures to develop biofuels)	Promote end use, Stimulate production of fuels	Transport	-	Biofuels	Financial incentive, Obligation	2019-2028	Limit incorporation of biofuels made from raw materials presenting a high risk of inducing ILUC (e.g., certain oils palm or soy), as provided for in REDII + ban of some biofuels (ex: produced from palm oil, PFAD, soy oil, food crops for biomethane production); sustainable aviation fuels objective
La taxe incitative relative à l'utilisation d'énergie renouvelable dans le transport (TIRUERT) pour favoriser l'incorporation de biocarburants (The incentive tax relating to the use of renewable energy in transport (TIRUERT) to promote the incorporation of biofuels)	Promote end use	Transport	-	Biofuels	Tax incentive	Start: 2005	Biofuels must comply with obligations relating to sustainability criteria

Stratégie de développement de la mobilité propre de la programmation pluriannuelle de l'énergie 2019-2028 (Clean mobility development strategy of the 2019-2028 multi-annual energy program)	Promote end use, Support innovation	Transport	-	Biofuels	Strategy	Start: 2019	-
Obligation d'incorporation de biocarburants dans les carburants aéronautiques (Obligation to incorporate biofuels into aeronautical fuels)	Promote end use	Transport	-	Biofuels	Obligation, Strategy	Start: 2019	Sustainable biofuels
Droit à l'injection (biométhane) (Right to injection (biomethane))	Stimulate production of fuels	Energy	-	Biogas	-	Start: 2019	-
Les tarifs d'achat pour le biométhane injecté dans les réseaux de gaz, en guichet ouvert (Purchase tariffs for biomethane injected into gas networks, open window)	Promote end use	Energy, Transport	-	Biogas	Tax incentive	Start: 2011	-

AAP en faveur de l'aval de la filière forêt bois AAP in favor of the downstream forest-timber sector)	Promote end use	Heating	Forest biomass	Solid biomass	-	Start: 2020	-
Les garanties d'origine pour la production d'énergie renouvelable (Guarantees of origin for renewable energy production)	Promote end use, Stimulate production of fuels	Electricity, Energy	Forest biomass	Biogas	Certificate	Start: 2006	Guarantees of origin for renewable gases
Renforcement du fonds chaleur : dispositif de soutien financier de projets de production de chaleur à partir d'énergies renouvelables (Strengthening the heat fund: financial support system for heat production projects from renewable energies)	Promote end use	Agriculture, Building, Heating, Industry	Agricultural biomass, Forest biomass	Biogas, Solid biomass	Financial incentive, Support scheme	2019-2028	-

Stratégie nationale de mobilisation de la biomasse et schémas régionaux biomasse (National biomass mobilization strategy and regional biomass plans)	Promote end use, Stimulate production of fuels	Energy	Forest biomass	Solid biomass	Strategy	Start: 2018	-
Indirect Measure(s)							
Volet forestier du Plan de Relance (Forestry component of the French Recovery Plan)	Stimulate availability of feedstocks, Stimulate production of fuels	-	Forest biomass	Solid biomass	Strategy, Support scheme	2021-2024	-
Programme national de la forêt et du bois et programmes régionaux de la forêt et du bois (National Forest and wood program and regional forest and wood programs)	Stimulate availability of feedstocks, Stimulate production of fuels	-	Forest biomass	Solid biomass	Strategy	2016-2026	-

Table 36: Overview of bioenergy measures for Croatia

Measure Name	Main Objective(s)	Sector Focus	Feedstock Focus	Fuel Focus	Measure Type	Implementation Timeframe	Way in which Sustainability of Biomass is Ensured

Decarbonization of transport through the production of advanced biofuels from residues of agricultural production and energy crops with integrated carbon capture, use and storage	Stimulate production of fuels	Transport	Residues	Biofuels (bioethanol), Biogas	-	2023-2026	In accordance with Part A of Annex IX of Directive 2018/2001, which includes biomass sustainability criteria
MTR-13: Advanced biofuel market development plan	Promote end use, Stimulate production of fuels	Transport	-	Biofuels	Regulatory/legislative change, Strategy	2023-2040	Implementation of measure is based on…establishment of conditions for monitoring the sustainability of biofuels and GHG savings
MWM-5: Use of biogas for biomethane production and electricity and heat generation	Promote end use, Stimulate production of fuels	Electricity, Heating, Transport	Wastes	Biogas, Biomethane	Obligation	2018-2040	-
MAG-4: Anaerobic decomposition of manure and biogas production	Promote end use, Stimulate production of fuels	Electricity	Wastes (manure)	Biogas	Strategy	2018-2040	-
MAG -15: Collection and processing of agricultural plantations and residues for energy purposes	Stimulate availability of feedstocks, Stimulate production of fuels	Energy	Agricultural biomass, Residues	Solid biomass	-	2023-2040	-
Indirect Measure(s)							

MCC-12: Foundation of the Platform for Bioeconomy	Support innovation	Agriculture, Forestry, Industry, Transport, Waste	-	-	Strategy	2023-2040	-
MTR-5: Legislative adjustments for cleaner transport	Promote end use	Transport	-	-	Regulatory/legislative change	Start: 2023	-
MEN-16: Information, education and capacity building for RES use	Promote end use	-	-	-	Strategy	Start: 2023	-
MEN-18: Promoting the RES use for production of electricity and heat	Promote end use	Electricity, Heating	-	-	Financial incentive	Start: 2014	-
MEN-19: Development of the regulatory framework for RES use	Promote end use	-	-	-	-	Start: 2023	-
MEN-22: Development and maintenance of centralised thermal systems	Energy security, Promote end use	Heating	-	Biofuels	-	2023-2040	-

Table 37: Overview of bioenergy measures for Hungary

Measure Name	Main Objective(s)	Sector Focus	Feedstock Focus	Fuel Focus	Measure Type	Implementation Timeframe	Way in which Sustainability of Biomass is Ensured
Government Decree 19/2009 (I. 30.) / on the implementing the provisions of Act XL of 2008 on natural gas supply	Energy security	Energy	-	Biogas	Regulatory/legislative change	Start: 2009	-
National policy framework for alternative fuels infrastructure development	Stimulate production of fuels	Transport	-	Biofuels	Financial incentive, Strategy	2016-2030	-
Mandatory blend rate of biofuels due to a change in legislation	Promote end use	Transport	-	Biofuels	Obligation, Regulatory/legislative change	Start: 2021	-
Green District Heating Programme	Promote end use, Stimulate production of fuels	Heating	Agricultural biomass	Biogas, Solid biomass	Strategy	Start: 2021	Increase the use of…biomass produced on the basis of sustainability criteria for heating/cooling purposes
Indirect Measure(s)							
Rural Development Programme, Priority Axis 5	Promote end use, Stimulate production of fuels	-	Residues, Wastes	-	Strategy, Tenders	2014-2025	-

Table 38: Overview of bioenergy measures for Ireland

Measure Name	Main Objective(s)	Sector Focus	Feedstock Focus	Fuel Focus	Measure Type	Implementation Timeframe	Way in which Sustainability of Biomass is Ensured
Renewables - Transport (With Additional Measures)	Promote end use	Transport	-	Biofuels (bioethanol and biodiesel)	Strategy	Start: 2022	-
Heat Pumps Non-Domestic (With Existing Measures)	Promote end use	Heating	-	Solid biomass	Financial incentive, Support scheme	Start: 2018	-

Heat Pumps Non-Domestic (With Additional Measures)	Promote end use	Heating	-	Solid biomass	Financial incentive, Support scheme	Start: 2022	-
Renewable Heat (ReHeat) Programme	Promote end use	Heating	-	Biogas, Solid biomass	Financial incentive, Strategy	2008-2011	-
Indirect Measure(s)							
Renewables - Heat (With Existing Measures)	Promote end use	Heating	-	Solid biomass	Obligation	Start: 2022	In line with requirements of Directive 2009/28/EC, which includes sustainability criteria
Greener Homes Scheme	Promote end use	Heating	Forest biomass	Solid biomass	Financial incentive, Strategy	2006-2011	-
Renewables - Transport (With Existing Measures)	Promote end use	Transport	-	Biofuels	Regulatory/legislative change	Start: 2005	-

Table 39: Overview of bioenergy measures for Italy

Measure Name	Main Objective(s)	Sector Focus	Feedstock Focus	Fuel Focus	Measure Type	Implementation Timeframe	Way in which Sustainability of Biomass is Ensured
Biocarburanti. Obbligo di immissione in consumo (aggiornamento) (Biofuels. Mandatory release for consumption (update))	Promote end use	Transport	-	Biofuels, Biomethane	Obligation	Start: 2021	-
Biocarburanti. Obbligo di immissione in consumo (Biofuels. Mandatory release for consumption)	Promote end use	Transport	-	Biofuels	Obligation	Start: 2006	Issue of Certificates of Release for Consumption to obligated entities that release sustainable biofuels for consumption (from 2018 also to producers of biomethane and advanced biomethane) + focus on sustainable biofuel inputs

Certificazione di sostenibilità dei biocarburanti. DM 14/11/2019 (Certification of sustainability of biofuels. DM 14/11/2019)	Safeguard sustainability	-	-	Biofuels	Certificate	Start: 2020	Establishment of National Biofuels Sustainability Certification System; aim to measure and verify environmental performance of biofuels during all major stages of the product life cycle, production, fuel production, and end use (including feedstock)
Certificazione di sostenibilità dei biocarburanti. Aggiornamento (Certification of sustainability of biofuels. Update)	Safeguard sustainability	-	-	Biofuels	Certificate	Start: 2023	Update of National Biofuels Sustainability Certification System to include provisions of Regulation 2022 and further characterization of supply chain
DM 2/3/2018. Incentivazione del biometano e altri biocarburanti avanzati (DM 2/3/2018. Incentivization of biomethane and other advanced biofuels)	Promote end use, Stimulate production of fuels	Energy, Electricity, Transport	Residues, Wastes, Algae	Biofuels, Biomethane	Certificate	Start: 2018	Certificates of Release for Consumption of biofuels
FER-E. DM 23/6/2016. Incentivazione rinnovabili elettriche non fotovoltaiche (RES-E. DM 23/6/2016. Non-photovoltaic electric renewables incentive)	Promote end use	Electricity, Energy	-	Biogas	Financial incentive, Tenders	Start: 2016	-

DM 15/9/2022. Incentivazione del biometano sostenibile (DM 15/9/2022. Incentivization of sustainable biomethane)	Promote end use, Stimulate production of fuels	Electricity, Energy	Agricultural biomass, Wastes	Biomethane	CAPEX subsidy, OPEX subsidy	Start: 2022	Incentivise sustainable biomethane
Nitrous oxide emissions reduction from manure management	Stimulate production of fuels	Agriculture	Residues	Biogas	Regulatory/legislative change, Strategy	Start: 2018	-
FER-2. Tecnologie innovative (FER-2. Innovative technologies)	Support innovation, Stimulate production of fuels	Electricity	-	Biogas, Solid biomass	Financial incentive	Start: 2023	-
Indirect Measure(s)							
Garanzie di Origine attestanti la produzione di energia elettrica da fonte rinnovabile (Guarantees of Origin attesting the production of electricity from renewable sources)	Safeguard sustainability	Electricity	-	Biogas, Biomethane	Certificate	Start 2011	Guarantees of origin attesting the production of electricity from renewable sources (biogas)
Garanzie d'Origine (aggiornamento) (Guarantees of Origin (update))	Safeguard sustainability	-	-	-	Certificate	Start: 2021	Guarantees of origin of biogas
Conto Termico (Thermal Account)	Promote end use	Heating	-	Solid biomass	Financial incentive	Start: 2012:	-

Table 40: Overview of bioenergy measures for Lithuania

Measure Name	Main Objective(s)	Sector Focus	Feedstock Focus	Fuel Focus	Measure Type	Implementation Timeframe	Way in which Sustainability of Biomass is Ensured

Waste management	Stimulate production of fuels	Waste	Wastes	Biogas, Biomethane	CAPEX subsidy, Strategy	Start: 2021	-
Implement local and renewable energy cogeneration plant projects, giving priority to Vilnius and Kaunas	Promote end use	Electricity, Heating	-	Biofuels	-	2018-2023	-
Mandatory blending of biofuels with mineral fuels	Promote end use, Stimulate production of fuels	Transport	-	Biofuels (biodiesel and bioethanol)	Obligation	2020-2030	-
Investment support for setting up biomethane plants	Stimulate production of fuels	Transport	-	Biomethane	CAPEX subsidy	2020-2030	-
Obligation imposed on operators of natural gas stations, supplying gas for direct consumption in transport	Promote end use	Transport	-	Biomethane	Obligation	2025-2030	-
New biofuel combustion plants in district heating	Promote end use, Stimulate production of fuels	Heating	-	Biofuels	-	2021-2030	-
Support for second generation bioethanol	Promote end use	-	-	Biofuels	-	2022-2026	-
Promotion to use biofuels for heat generation in district heating systems	Promote end use	Heating	-	Biofuels	-	2018-2023	-
Promotion of small-scale biomass cogeneration	Promote end use	Electricity, Heating	-	Solid biomass	-	2019-2022	-

Investment support for implementing climate-friendly farming methods in livestock farms	Promote end use, Stimulate availability of feedstocks	Agriculture	Wastes	Biogas	CAPEX subsidy, Strategy	2023-2027	-
Investment support for implementing climate-friendly farming methods in livestock farms	Promote end use, Stimulate production of fuels	Agriculture	Wastes	Biogas	CAPEX subsidy	2020-2030	-
Indirect Measure(s)							
Change in pollution technologies	Promote end use	Industry	-	Solid biomass	-	2014-2022	-
Promoting the development of alternative fuels infrastructure and transport	Promote end use	Transport	-	Biogas	-	2016-2027	-
Promoting the development of alternative fuels infrastructure and transport	Promote end use	Transport	-	Biogas	-	2023-2030	-
RES use in industry	Promote end use	Industry	-	-	Support scheme	2022-2030	Sustainable biomass used as an example of RES
Restoration of wetlands	Promote end use	-	Agricultural biomass	Biogas	Strategy	2023-2027	-
Investments in bioeconomy businesses	Promote end use, Support innovation	Agriculture	-	-	CAPEX subsidy, Strategy	2023-2027	-

Table 41: Overview of bioenergy measures for Luxembourg

Measure Name	Main Objective(s)	Sector Focus	Feedstock Focus	Fuel Focus	Measure Type	Implementation Timeframe	Way in which Sustainability of Biomass is Ensured

Rémunérations pour l'électricité produite à partir des sources d'énergie renouvelables (Remu neration for electricity produced from renewable energy sources)	Promote end use	Electricity, Heating	Wastes	Biogas, Solid biomass	Regulatory/legislative change, Support scheme	Start: 2014	Mention of system of guarantees of origin; "with view to the objectives set out in REDII", which includes sustainability criteria
Rémunérations pour le biogaz injecté dans le réseau de gaz nature (Remuneration for biogas injected into the natural gas network)	Promote end use	Energy	Wastes	Biogas	Support scheme	-	-
Stratégie biogaz et nouveaux incitatifs (financiers et autres) pour le biogas (Biogas strategy and new incentives (financial and others) for biogas)	Promote end use	Electricity, Energy	Wastes	Biogas	Financial incentive, Strategy	Start: 2023	Transposition of the sustainability and GHG reduction criteria provided for in REDII of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy produced from renewable sources in national law
Régime d'aides en faveur des communes (Aid scheme for municipalities)	Promote end use	Electricity, Heating	-	Solid biomass	Support scheme	Start: 2021	-

Obligation d'incorporation de biocarburants durables aux carburants routiers (Obligation to incorporate sustainable biofuels into road fuels)	Promote end use	Transport	-	Biofuels, Biogas, Bioliquids, Solid biomass	Obligation	2022-2050	Sustainable biofuels; with respect for sustainability criteria; limit on biofuels produced from cereals, etc. and from crops grown for energy production on agricultural land; limit for biofuels, bioliquids, and combustibles from biomass with high ILUC risk; limit for the use of first generation biofuels
Biométhane dans le secteur des transports (Biomethane in the transport sector)	Promote end use	Transport	-	Biomethane	-	2022-2023	-
Valorisation des déchets de verdure (Recovery of green waste)	Promote end use, Stimulate availability of feedstocks	Heating	Forest biomass, Wastes	Solid biomass	-	Start: 2015	-
Valorisation des déchets organiques (Recovery of organic waste)	Promote end use, Stimulate availability of feedstocks, Stimulate production of fuels	Energy	Wastes	Biogas	-	Start: 2011	-
Terres arables - gestion des terres arables (Arable land - arable land management)	Stimulate production of fuels	-	Agricultural biomass	Solid biomass	-	-	-
Indirect Measure(s)							

Stratégie de décarbonation du transport de marchandises et du secteur logistique (Decarbonization strategy for freight transport and the logistics sector)	Promote end use	Transport	-	Biofuels	Strategy	-	-

Table 42: Overview of bioenergy measures for Latvia

Measure Name	Main Objective(s)	Sector Focus	Feedstock Focus	Fuel Focus	Measure Type	Implementation Timeframe	Way in which Sustainability of Biomass is Ensured
Biofuel Blend Obligation	Promote end use	Transport	-	Biofuels (bioethanol and biodiesel)	Obligation	Start: 2010	-
Promote the production of biogas and biomethane and the use of biomethane	Promote end use, Stimulate production of fuels	-	Wastes (manure)	Biogas, Biomethane	-	2023-2030	-
Indirect Measure(s)							
RES Technologies in Single Family, Two-apartment and Twin buildings	Promote end use	Heating	-	Solid biomass	Financial incentive	2022-2024	-
Investment Support Programme for District Heating (DH) Systems: 2014-2020 EU Funds programming period	Promote end use	Heating	-	Solid biomass	CAPEX subsidy	2017-2023	-
Excise Tax – Transport sector	Promote end use	Transport	-	Biofuels (bioethanol and biodiesel)	Tax incentive	Start: 1993	-

Table 43: Overview of bioenergy measures for Malta

Measure Name	Main Objective(s)	Sector Focus	Feedstock Focus	Fuel Focus	Measure Type	Implementation Timeframe	Way in which Sustainability of Biomass is Ensured
Biofuels Substitution Obligation (2021-2030)	Promote end use	Transport	-	Biofuels	Obligation	2021-2030	Inclusion of sustainability criteria in REDII; in line with the requirements of the RED II recast

Table 44: Overview of bioenergy measures for The Netherlands

Measure Name	Main Objective(s)	Sector Focus	Feedstock Focus	Fuel Focus	Measure Type	Implementation Timeframe	Way in which Sustainability of Biomass is Ensured
ISDE Investment subsidies small renewable energy systems	Promote end use, Stimulate production of fuels	Heating	-	Solid biomass	CAPEX subsidy	2015-2030	-
Indirect Measure(s)							
Demonstration schema Climate technologies & innovations in transport	Support innovation	Transport	-	-	Support scheme	2017-2021	-
Prohibiting coal for electricity generation	Promote end use	Electricity	-	Solid biomass	Obligation	2020-2030	Sustainable biomass listed as an example
Subsidy scheme LNG	Promote end use	Transport	-	Biogas	CAPEX subsidy	2020-2021	-

Table 45: Overview of bioenergy measures for Poland

Measure Name	Main Objective(s)	Sector Focus	Feedstock Focus	Fuel Focus	Measure Type	Implementation Timeframe	Way in which Sustainability of Biomass is Ensured
Feed-in tariff and feed-in premium schemes for RES	Promote end use	Electricity	-	Biogas, Solid biomass	CAPEX subsidy, OPEX subsidy	2016-2035	-

Promotion of biofuels	Promote end use	Transport	-	Biofuels	Financial incentive, Support scheme	2006-2030	System for the certification of the quality and use of biofuels
Development of agricultural biogas plants	Promote end use, Stimulate production of fuels	Agriculture, Electricity, Heating	Agricultural biomass	Biogas	-	2010	-
Wspieranie działań adaptacyjnych i redukujących emisję w gospodarstwach rolnych (Supporting adaptation and emission reduction activities on farms)	Promote end use, Stimulate production of fuels	Agriculture	-	Biogas, Solid biomass	Support scheme	2023-2027	-
Indirect Measure(s)							
Scheme of certificates of origin for RES (the green certificate scheme)	Promote end use, Safeguard sustainability	Electricity	-	Biogas	Certificate, Support scheme	2005-2031	Renewable energy certificates of origin system
"District Heating" Priority Programme	Promote end use	Heating	-	-	Financial incentive, Strategy	2019-2050	-

Wsparcie przedsiębiorstw działających w dziedzinie efektywności energetycznej i OZE z preferencją dla firm będących dostawcami usług energetycznych (działające w formule ESCO) (Support for companies operating in the field of energy efficiency and renewable energy, with preference for companies providing energy services (operating in the ESCO formula))	Promote end use	-	-	-	Support scheme	2021	-
Rozwój instalacji do wytwarzania ciepła z OZE (Development of installations for generating heat from renewable energy sources)	Stimulate production of fuels	Heating	-	-	Regulatory/legislative change, Support scheme	2021-2050	-

Table 46: Overview of bioenergy measures for Portugal

Measure Name	Main Objective(s)	Sector Focus	Feedstock Focus	Fuel Focus	Measure Type	Implementation Timeframe	Way in which Sustainability of Biomass is Ensured
Regulamentar a injeção de gases renováveis (Regulate the injection of renewable gases)	Promote end use, Stimulate production of fuels	Energy	-	Biogas	Regulatory/legislative change	2020-2022	-

Fomentar um melhor aproveitamento da biomassa para usos energéticos (Encouraging better use of biomass for energy purposes)	Promote end use, Stimulate availability of feedstocks, Stimulate production of fuels	Electricity, Energy	Forest biomass	Solid biomass	-	2019-2020	-
Incentivar J&D&I em energias renováveis, armazenamento, hidrogénio, biocombustíveis avançados e outros combustíveis 100% renováveis (Incentivize R&D&I in renewable energy, storage, hydrogen, advanced biofuels and other 100% renewable fuels)	Support innovation	-	-	Biofuels	Financial incentive	-	-
Accelerate national energy transition to renewables	Promote end use, Stimulate availability of feedstocks	Agriculture, Industry	-	Biogas, Solid biomass	Strategy	Start: 2013	-
Promote R&D projects that support the transition to a carbon neutral economy	Support innovation	-	-	Biofuels	Strategy	Start: 2020	-
Promover a utilização eficiente de energias renováveis nos sistemas de aquecimento e arrefecimento (Promote efficient use of renewable energy in heating and cooling systems)	Promote end use, Support innovation	Heating	-	Biogas, Solid biomass	Financial incentive	2020-2030	-

To promote the production and consumption of alternative renewable fuels, namely Hydrogen including through development of alternative fuels infrastructure for clean fuels	Promote end use, Stimulate production of fuels	Transport	-	Biofuels	Strategy	Start: 2017	-
Indirect Measure(s)							
Estudar e definir metas de incorporação de gases renováveis (Study and define goals for incorporating renewable gases)	Promote end use	Energy	-	Biogas	Strategy	2020-2021	-
Promover programas nacionais de I&I para apoio ao desenvolvimento tecnológico (Promote national R&I programs to support technological development)	Support innovation	-	-	-	-	2020-2030	-
To promote decarbonisation of industry through eco-innovation and cleaner production processes and to promote industry digitization.	Promote end use, Support innovation	Industry	-	Biofuels, Biogas, Solid biomass	Strategy	Start: 2020	-

Reduction of waste production and of landfill disposal and promotion of recycling.	Reduce landfill, Stimulate availability of feedstocks, Stimulate production of fuels	Energy, Waste	Wastes	Biofuels	Strategy	Start: 2014	-
To promote the production and use of renewable energy sources in the agricultural and forestry sectors; To adopt agriculture and forestry hydric and energy efficiency measures.	Promote end use, Stimulate availability of feedstocks, Stimulate production of fuels	Agriculture, Forestry	-	-	Strategy	Start: 2014	-
Promover a formação de técnicos especializados (Promote the training of specialized technicians)	Support innovation	-	-	Biofuels	-	2020-2030	-
To promote energy and resource efficiency, renewables and electrification; Industrial symbioses, resource optimization and resource reuse.	Promote end use, Support innovation	Industry	-	-	-	Start: 2013	-

Promover a cogeração renovável e reduzir de forma gradual os incentivos à cogeração a partir de combustíveis fósseis (Promoting renewable cogeneration and gradually reducing incentives from fossil fuel cogeneration)	Promote end use, Stimulate production of fuels	Electricity, Heating	-	-	Tax incentive	2020-2025	-
Definir e implementar um sistema de certificação de qualidade para os gases renováveis (Define and implement a quality certification system for renewable gases)	Safeguard sustainability	Energy	-	Biogas	Certificate, Strategy	2020-2025	-

Table 47: Overview of bioenergy measures for Romania

Measure Name	Main Objective(s)	Sector Focus	Feedstock Focus	Fuel Focus	Measure Type	Implementation Timeframe	Way in which Sustainability of Biomass is Ensured
GEO no. 80/2018 relating to the quality of petrol and diesel fuels and introducing a mechanism to monitor and reduce greenhouse gas emissions, with subsequent amendment (Law no. 311/2018)	Promote end use	Transport	-	Biofuels	Obligation	Start: 2018	-

Decision no. 195/2022 for the approval of the State Aid Scheme regarding the support of investments intended to promote the production of energy from less exploited renewable sources, namely biomass, biogas, geothermal energy, and the State Aid Scheme regarding the support of investments in high-efficiency cogeneration	Promote end use	Energy	-	Biogas, Solid biomass	Support scheme	2022-2023	-
Law no. 254 of July 20, 2022 for the amendment and completion of the Land Fund Law no. 18/1991 and other normative acts	Promote end use	Electricity	-	Biogas, Bioliquids, Solid biomass	CAPEX subsidy	2022-2023	-
Indirect Measure(s)							
Law no. 220/2008 on establishing the promotion system for the production of energy from renewable energy sources, amended by Law no. 139/2010 and GEO no. 163/2022	Promote end use	Energy	-	Biogas, Solid biomass	Regulatory/legislative change, Strategy	2010-2030	-

Decision No. 1.172 of September 21, 2022 for the approval of the National Strategy for Forests 2030	Promote end use, Stimulate availability of feedstocks	Energy	Forest biomass	Solid biomass	Strategy	2022-2030	-

Table 48: Overview of bioenergy measures for Sweden

Measure Name	Main Objective(s)	Sector Focus	Feedstock Focus	Fuel Focus	Measure Type	Implementation Timeframe	Way in which Sustainability of Biomass is Ensured
Biowaste collection and treatment	Reduce landfills, Stimulate availability of feedstocks, Stimulate production of fuels	-	Wastes	Biogas	Regulatory/legislative change	Start: 2024	-
Tax reduction for biofuels	Promote end use	Transport	-	Biofuels	Tax incentive	Start: 2004	Sustainable biofuels are still exempted from both the carbon tax and the energy tax from July 2018
Support for biogas production	Stimulate production of fuels	Electricity, Energy, Heating, Transport	Wastes (manure)	Biogas	CAPEX subsidy, Support scheme	Start: 2015	-
Emission reduction obligation for certain fossil fuels	Promote end use, Safeguard sustainability, Stimulate production of fuels	Transport	-	Biofuels	Obligation	Start: 2018	Blending with sustainable biofuels
Carbon dioxide tax	Promote end use	Transport	-	Biofuels	Tax incentive	Start: 1991	-
Fertilizer gas support	Stimulate production of fuels	-	Wastes (manure)	Biogas	CAPEX subsidy	2014-2023	-
Indirect Measure(s)							

Forest Policy and the Forest Act	Stimulate availability of feedstocks	Forestry	-	-	Strategy	Start: 1993	-
Local climate investment program (Climate Leap)	Promote end use, Stimulate production of fuels	-	-	Biofuels, Biogas	CAPEX subsidy, Strategy	Start: 2015	-
A national center for carbon dioxide capture and storage	Promote end use	-	-	-	Financial incentive	Start: 2021	-

Table 49: Overview of bioenergy measures for Slovenia

Measure Name	Main Objective(s)	Sector Focus	Feedstock Focus	Fuel Focus	Measure Type	Implementation Timeframe	Way in which Sustainability of Biomass is Ensured
Investment grants for electricity generation from renewable energy sources (RES-E) and from high-efficiency cogeneration (CHP)	Promote end use	Electricity, Heating	-	Solid biomass	CAPEX subsidy	Start: 2022	-
Minimal share of renewable energy in transport	Promote end use	Transport	-	Biofuels	Obligation	Start: 2005	According to the EU Directives 2009/28/EC and 2015/1315/EU, which include biomass sustainability criteria
Promotion of low emission animal rearing practices	Stimulate production of fuels	-	Wastes (manure)	Biogas	CAPEX subsidy	Start: 2004	-
Upgrade of support scheme and preparation of new support scheme for the promotion of electricity generation from RES and CHP with high-efficiency	Promote end use	Electricity, Heating	Forest biomass	-	Support scheme	Start: 2021	-

Additional measures for higher share of RES in transport fuels	Promote end use, Stimulate production of fuels	Transport	Annex IX	Biofuels	-	Start: 2023	-
Incentives for investment in fixed assets that improve the overall efficiency of the agricultural holding and in infrastructure related to the development and adaptation of agriculture	Stimulate production of fuels	-	Wastes (manure)	Biogas	CAPEX subsidy	Start: 2023	-
Technological modernisation of thermal electricity plants	Support innovation	Electricity, Heating	Forest biomass	Solid biomass	Strategy, Support scheme	Start: 2023	-
Feed-in tariffs support scheme for electricity generated from renewable energy sources (RES-E) and from high-efficiency cogeneration (CHP)	Promote end use	Electricity, Heating	-	Biogas, Solid biomass	OPEX subsidy, Support scheme	Start: 2022	-
Indirect Measure(s)							
Providing conditions for further integration of markets and construction of necessary infrastructure	Energy security, Stimulate production of fuels	Electricity, Energy	-	Biogas	-	Start: 2023	-

Table 50: Overview of bioenergy measures for Slovakia

Measure Name	Main Objective(s)	Sector Focus	Feedstock Focus	Fuel Focus	Measure Type	Implementation Timeframe	Way in which Sustainability of Biomass is Ensured

Effectively process animal waste and use biogas as a local energy source	Promote end use, Stimulate production of fuels	Energy	Wastes	Biogas	-	Start: 2025	-
Collection of biodegradable municipal waste	Reduce landfill, Stimulate availability of feedstocks, Stimulate production of fuels	Electricity, Heating, Transport	Wastes	Biogas	Regulatory/legislative change	Start: 2023	-
Mandatory blending of bio-components into motor fuels	Promote end use	Transport	-	Biofuels	Obligation	2006-2030	-
Mandatory blending of advanced biofuels into motor fuels	Promote end use	Transport	-	Biofuels	Obligation	2019-2030	-
Green Households	Promote end use	Building, Heating	-	Solid biomass	Support scheme	Start: 2015	-
Implementation of the Fit for 55 package	Promote end use	Electricity, Heating	-	Solid biomass	Strategy	Start: 2022	-
Implementation of the EU Emissions Trading System	Promote end use, Stimulate production of fuels	Energy	-	Solid biomass	Regulatory/legislative change	Start: 2013	-
Increased share of renewable energy in road transport fuel consumption	Promote end use	Transport	-	Biofuels	Obligation	Start: 2010	-
Indirect Measure(s)							
Modernisation of Energy Systems	Promote end use, Support innovation	Energy	-	Solid biomass	CAPEX subsidy	2022-2030	-
Renovation of buildings – Family houses – EPC	Promote end use	Building, Heating	-	Biogas, Solid biomass	Strategy	Start: 2021	-

Annex IV: Information reported on environmental impacts related to biofuel/bioliquid production in MS Progress Reports in Annex XVI, table 5.

At the time of writing, only 12 MSs reported any information on environmental impacts related to biofuel or bioliquids in Annex XVI. The following MSs did not report information in that section: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Finland, France, Greece, Italy, Latvia, Lithuania, Portugal, Slovakia. At the time of this report, Germany, Romania, Ireland, and Poland still had outstanding submissions. The remainder of reporting can be found in the table below.

Table 51: Information provided in MS Progress Reports to Annex XVI, table 5. Source: MS Progress Reports

Member State	Information reported on environmental impacts related to biofuel/bioliquid production
Estonia	The Estonian Progress Report only states that 'no biofuels or bioliquid production in Estonia, and that regarding biomethane production there is no impact known or researched.' Regarding the use of biofuels, the country only reports on impacts relating to forest biomass. A forest monitoring scheme is implemented and shows that forests are of 'mediocre ecological state' which has been slightly improving or remaining stable. The report further states that there are no specific assessments made regarding the impact of woody biomass used for energy purposes on water, soil, and air quality.
Hungary	The Hungarian Progress Report states multiple initiatives to monitor and maintain forests. These include mandatory regeneration after felling to maintain optimal water characteristics and minimization of soil damage from forest management and obligatory recovery measures. Additionally, 'the level of naturalness' should be improved or maintained through forest management. There is no information reported on other crops.
Luxembourg	Luxembourg reports that there is no data available or that it is incomplete.
Malta	Malta reports the impact on air quality by reporting emissions from the use of biofuels. Activity data was modelled to predict emission scenarios until 2040 dependent on fleet characteristics and mileage activity. NO_2, SO_2, PM2.5, NH_3, and NMVOC emissions are all expected to decrease.
Netherlands	The Netherlands reports that 'only a very limited amount (1.3%) of conventional fuels were based on food and feed crop' which were mostly imported and that negative consequences occurring abroad are prevented by the RED sustainability criteria. Thus, it concludes that 'the impact on biodiversity, water resources, water quality, and soil quality' is 'immaterial in the Netherlands'.
Slovenia	Slovenia does not report information on biodiversity, soil, and water impacts. On air quality, it reports that air pollution from PM10 and PM2.5 have reduced by 48% and 38% respectively from a 2005 baseline. However, in its reporting, it is stated that the largest source for PM2.5 and 10 is linked to heating, especially household fireplaces.
Spain	Spain reports that the Royal Decree 1597/2011 regulated sustainability criteria for biofuels and bioliquids as well as a National Sustainability Verification System, but further states that 'due to the currently scarce use of national raw materials for the production of biofuels, the impacts […] are considered not relevant.'.
Sweden	Swedish reports state that air quality, biodiversity, water quality, and soil health are critical aspects to consider when analyzing the sustainability of biofuels. There is no reporting on air quality impacts. On biodiversity, Sweden reports that negative impacts due to land use change, e.g., the drainage of peatlands, should be avoided and names measures to increase biodiversity, such as protection of habitats, and refers to the requirements of the REDII. Regarding soil quality, the report discusses avoiding negative impacts on soils due to acidification, avoiding nutrient loss and carbon stock fluxes leading to emissions.

GETTING IN TOUCH WITH THE EU

In person

All over the European Union there are hundreds of Europe Direct information centres. You can find the address of the centre nearest you at: https://europa.eu/european-union/contact_en

On the phone or by email

Europe Direct is a service that answers your questions about the European Union. You can contact this service:

– by freephone: 00 800 6 7 8 9 10 11 (certain operators may charge for these calls),

– at the following standard number: +32 22999696, or

– by email via: https://europa.eu/european-union/contact_en

FINDING INFORMATION ABOUT THE EU

Online

Information about the European Union in all the official languages of the EU is available on the Europa website at: https://europa.eu/european-union/index_en

EU publications

You can download or order free and priced EU publications from: https://op.europa.eu/en/publications. Multiple copies of free publications may be obtained by contacting Europe Direct or your local information centre (see https://europa.eu/european-union/contact_en).

EU law and related documents

For access to legal information from the EU, including all EU law since 1952 in all the official language versions, go to EUR-Lex at: http://eur-lex.europa.eu

Open data from the EU

The EU Open Data Portal (http://data.europa.eu/euodp/en) provides access to datasets from the EU. Data can be downloaded and reused for free, for both commercial and non-commercial purposes.

MJ-02-24-019-EN-N

Publications Office
of the European Union

ISBN 978-92-68-11513-8