# EU 2040 Climate Target: Contributions of non-$CO_2$ emissions

## Part 6 of 7 studies on sectoral contributions to the 2040 target

Lorenz Moosmann (Öko-Institut)
Jakob Graichen (Öko-Institut)
Mateo Flohr Reija (Öko-Institut)

**Final report**

24 July 2024

## Contact

Lorenz Moosmann
Senior Researcher
Öko-Institut e.V.
Borkumstr. 2
13189 Berlin

E-Mail: <l.moosmann@oeko.de>

## Suggested citation

Moosmann, Lorenz, et al. (2024): EU 2040 Climate Target: Contributions of non-$CO_2$ emissions. Ecologic Institute and Öko-Institut, Berlin

This study is part of the project "EU 2040 Climate Target: Level of ambition and implications" https://www.oeko.de/en/projects/detail/new-objective-and-necessary-increase-in-ambition-for-eu-climate-protection-by-2040/.

## Acknowledgements

The Federal Ministry of Economy and Climate Action (BMWK) funded this report. Ecologic Institute and Öko-Institut are very appreciative of this support. Opinions expressed in this report represent the views of the authors and do not necessarily represent the position of the BMWK.

## Ecologic Institute: Science and policy for a sustainable world

Ecologic Institute is an independent, academic think tank for environmental research and policy analysis. Since our founding in 1995, Ecologic Institute has been dedicated to improving environmental policy, sustainable development and policy practice. Through findings and ideas Ecologic Institute helps to mainstream environmental issues into other policy areas. Strengthening the European and international dimensions in research, education and environmental policy discourses is a key priority. Ecologic Institute has offices in Berlin, Brussels and Washington DC.

Today more than 100 employees work for Ecologic Institute. Our colleagues come from over 25 countries. Offering diverse expertise and skills, our experts cover the entire spectrum of environmental policy, sustainable development and socio-ecological research in inter- and transdisciplinary projects. Our staff researches, supports and evaluates national, European and international political processes and brings together actors from science, politics and practice. The results are in-depth analyses and practical recommendations. In cooperation with leading American and German universities, the Institute is also active in education.

Ecologic Institute is a private, non-profit institution financed through its project work. Funding partners include the European Commission, the European Parliament, the German Federal Ministry for the Environment, the German Federal Ministry of Education and Research, the German Federal Environment Agency and various foundations.

Ecologic Institute is a member of the Ecological Research Network (Ecornet).

Ecologic Institute is a registered charity. Donations are tax deductible.

Ecologic Institute in Washington DC is an IRC 501 (c) (3) non-profit organization.

Further information: **www.ecologic.eu**

# Contents

## List of Figures



## Abbreviations

| | |
|---|---|
| **$CH_4$** | Methane |
| **CO** | Carbon Monoxide |
| **$CO_2$** | Carbon Dioxide |
| **BC** | Black Carbon |
| **$CH_4$** | Methane |
| **CO** | Carbon Monoxide |
| **$CO_2$** | Carbon Dioxide |
| **$CO_2e$** | Carbon Dioxide equivalent |
| **CRF** | Common Reporting Format |
| **ECL** | European Climate Law |
| **EEA** | European Environment Agency |
| **E-fuels** | Electrofuels |
| **ETS** | Emissions Trading System |
| **F-gases** | Fluorinated Gases |
| **GHG** | Greenhouse Gas |
| **$H_2$** | Hydrogen |
| **HFC** | Hydrofluorocarbon |
| **IPCC** | Intergovernmental Panel on Climate Change |
| **IPPU** | Industrial Processes and Product Use |
| **LULUCF** | Land Use, Land Use Change and Forestry |
| **MRV** | Monitoring, reporting and verification |
| **Mt** | Million tonnes |

| | |
|---|---|
| **Mtoe** | Million tonnes oil equivalent |
| **$N_2O$** | Nitrous Oxide |
| **NMVOC** | Non-Methane Volatile Organic Compounds |
| **NO** | Nitrogen Oxide |
| **$NO_2$** | Nitrogen Dioxide |
| **$NO_X$** | Nitrogen Oxides |
| **PFC** | Perfluorocarbon |
| **$PM_{2.5}$** | Fine particulate matter |
| **$SF_6$** | Sulphur Hexafluoride |
| **$SO_2$** | Sulphur Dioxide |

# Executive summary

The European Commission presented its communication on the EU 2040 climate target in February 2024. It recommended reducing the EU's net greenhouse gas emissions by 90% by 2040 compared to 1990. The 2040 climate target will be a pivotal milestone on the EU's journey towards achieving climate neutrality by 2050.

While carbon dioxide is the most important anthropogenic greenhouse gas and is addressed by comprehensive EU policies and measures, other greenhouse gases are relevant for achieving the EU's climate targets as well. In the time horizon up to 2040, when $CO_2$ emissions in the EU are projected to decrease substantially, the relative importance of non-$CO_2$ emissions will increase.

Methane is the most important greenhouse gas besides $CO_2$. The main source of methane emissions is the agriculture sector, followed by the waste and energy sectors. Nitrous oxide emissions originate mainly from agriculture, and to a lesser extent from energy systems and wastewater. In addition to emission reductions in the agriculture sector (addressed in a separate paper), new policies are needed to ensure an adequate contribution to meeting the 2040 target:

- In the waste sector, incentives need to be introduced to effectively reduce the landfilling of organic waste and to capture methane emissions from landfills. Pricing mechanisms, including a possible inclusion in the ETS, should be explored. Besides pricing mechanisms, improved regulations can also help reduce methane emissions from the waste sector.
- In order to reduce fugitive emissions from the energy sector, regulations need to be strengthened and extended in areas which are not the focus of the Methane Regulation. These include fugitive emissions from biogas production.
- To reduce nitrous oxide emissions from wastewater, additional treatment steps need to be introduced in wastewater treatment.

Fluorinated gases (F-gases) are mostly emitted during the use of such gases in refrigeration and air conditioning. Emissions of water vapor, another greenhouse gas, have an important warming effect in the stratosphere. Besides these non-$CO_2$ greenhouse gases, additional substances affect climate change. These include the short-lived climate forcers hydrogen, nitric oxide, non-methane volatile organic compounds, carbon monoxide, sulphur dioxide and black carbon.

While the emissions of most of these climate forcers are projected to decrease in the coming decade, water vapor emissions in the stratosphere will increase with growing air transport. These emissions need to be addressed by policies that target overall air transport, such as the EU ETS. The emissions of hydrogen are also expected to increase with its use as a main alternative to fossil fuels and feedstocks. Regulations for leak detection and repair are needed to help reduce these emissions.

# 1 Introduction

The EU will adopt a climate target for 2040 in the coming years. This is a legal obligation set out in the European Climate Law (ECL). Article 4.4 of the ECL stipulates that "a Union-wide climate target for 2040 shall be set" – with a view to achieving the ECL's climate neutrality objective. Once the target is adopted, the EU is also set to adopt a legislative package to implement this target. This package will reform relevant EU laws and policies.

This paper is part of a group of sectoral papers, published in the context of a project funded by the German Federal Ministry for Economic Affairs and Climate Action. In this project, Ecologic and Oeko-Institute analyse the ambition level of the 2040 target and examine the impacts of a new 2040 target on Member States, sectors, and instruments. For more information about this project see: EU 2040 Climate Target. Level of ambition and implications. Besides other outputs of this project, these sectoral papers explore contributions of respective sectors to the upcoming 2040 climate target and what it takes for these sectors to achieve the related emission reductions. Relying on various emission reduction scenarios, the papers discuss different measures and policies that could help achieve the necessary contributions.

While carbon dioxide ($CO_2$) is the most important anthropogenic greenhouse gas (GHG) and is addressed by comprehensive EU policies and measures, other greenhouse gases are relevant for achieving climate targets as well. In the time horizon up to 2040, when $CO_2$ emissions in the EU are projected to decrease substantially, the relative importance of non-$CO_2$ emissions will increase. The following non-$CO_2$ greenhouse gases are particularly relevant:

- **Methane ($CH_4$)**: In 2021, methane, expressed in $CO_2$ equivalents, accounted for approximately 13% of total GHG emissions in the EU (excluding Land Use, Land Use Change and Forestry – LULUCF). The main sources of methane emissions are agriculture[1] (56% of total methane emissions), followed by the waste sector (24%) and the energy sector (17%). Within the energy sector, 38% of emissions originate from incomplete combustion processes, mainly in residential buildings, 37% originate from coal mines, 20% from gas production, transmission, distribution and related processes, and 5% from oil production and related processes (EEA 2023).
- **Nitrous oxide ($N_2O$)**: In 2021, $N_2O$ emissions accounted for approximately 6% of total GHG emissions in the EU (excluding LULUCF). The main sources of $N_2O$ emissions are agriculture[2] (74% of total $N_2O$ emissions), followed by the energy sector (12%). The Industrial Processes and Product Use (IPPU), waste and LULUCF sectors are minor sources, amounting to 4%, 5% and 6% of total $N_2O$ emissions in the EU, respectively (EEA 2023).
- **Fluorinated gases (F-gases)**: In 2021, fluorinated gases accounted for approximately 2% of total GHG emissions in the EU. These emissions originate mostly from the use of such gases in refrigeration and air conditioning – these uses account for 82% of total F-gas emissions (EEA 2023).

[1] Methane emissions from the agriculture sector are addressed in the separate paper 'EU 2040 climate Target: Contributions of the agriculture sector'.
[2] Nitrous oxide emissions from the agriculture sector are addressed in the separate paper 'EU 2040 climate Target: Contributions of the agriculture sector'

- **Water vapor** is the main non-anthropogenic greenhouse gas in the atmosphere. Unlike many other greenhouse gases, its global concentration has not been changed substantially by human activities. However, emissions of water vapor from airplanes in the stratosphere have a particularly high warming effect.

Besides these non-$CO_2$ greenhouse gases, additional substances contribute to climate change, either as indirect climate forcers or as aerosols:

- **Hydrogen ($H_2$)**: Hydrogen is an indirect greenhouse gas as it affects the concentration of other greenhouse gases in the atmosphere. Specifically, hydrogen in the atmosphere slows the oxidation of methane, and it contributes to the formation of ozone and water vapor (Ocko Hamburg 2022). There are no national or international inventories of hydrogen emissions. Such emissions will become more relevant as hydrogen is expected to become one of the main alternatives to fossil fuels and feedstocks.
- **Nitrogen dioxide ($NO_2$), non-methane volatile organic compounds (NMVOC) and carbon monoxide (CO)** are indirect greenhouse gases that contribute to the formation of the greenhouse gas ozone. In addition, CO in the atmosphere slows the oxidation of methane. During many combustion processess, nitrogen oxide (NO) is emitted alongside $NO_2$ and converted into $NO_2$ in the atmosphere. Hence, in air pollutant emissions inventories, the sum of these two gases is provided as **nitrogen oxides ($NO_x$)**.
- **Sulphur dioxide ($SO_2$)** is an indirect climate forcer that contributes to aerosol formation, which in turn can have a cooling effect by reflecting sunlight and by contributing to cloud formation.
- **Black carbon (BC)** is an aerosol that contributes to warming by absorbing solar energy.

A number of EU policies address the emissions of the various greenhouse gases and other substances, although some are not as comprehensive as those addressing $CO_2$.

- While there is no overarching EU policy specifically addressing **methane** emissions from agriculture, methane emissions in the waste sector have been reduced substantially in many EU Member States through the implementation of the Landfill Directive[3]. Concerning fugitive emissions in the energy sector, the Methane Regulation[4] lays down the rules for monitoring, reporting and verification of methane emissions, and for abating these emissions.
- There is no overarching EU policy specifically addressing **nitrous oxide** emissions from the agriculture sector. The same is true for the energy sector, but $N_2O$ emissions are reduced through the implementation of policies that aim at reducing combustion processes, such as the EU Emissions Trading System (ETS) or $CO_2$ standards in road transport[5]. Industrial processes used to be an important source of $N_2O$ emissions. Emissions of key processes such as nitric acid production are subject to the EU ETS, and they have been reduced substantially in the past two decades through the implementation of abatement measures (EEA 2023).

---

3 Directive (EU) 2018/850 amending Directive 1990/31/EC on the landfill of waste, http://data.europa.eu/eli/dir/2018/850/oj.

4 Regulation (EU) 2024/1787 on methane emissions reductions in the energy sector and amending Regulation (EU) 2019/942, https://eur-lex.europa.eu/eli/reg/2024/1787/oj.

5 Such emissions from the energy sector are addressed in the separate paper ‘EU 2040 climate Target: The energy supply sector’.

- The emissions of **F-gases** have been reduced recently through the implementation of the F-gas Regulation[6], and further emission reductions will follow from the implementation of its latest revision[7].
- The emissions of **$NO_x$, NMVOC, $SO_2$** and fine particulate matter (which is related **to black carbon**) are addressed by the National Emission Reduction Commitments Directive[8].

As some of these non-$CO_2$ emissions gain in importance relative to $CO_2$ in the period after 2030, it is critical to address them in the 2040 target framework. However, the following challenges need to be taken into account:

- Some of these emissions are hard to abate (such as methane and nitrous oxide emissions from some agricultural activities).
- For several of these emissions, there is a multitude of small sources (such as fugitive emissions from fuels).
- For some gases, adequate alternatives are currently not available (such as for some F-gases).
- Many non-$CO_2$ emissions are difficult to monitor.
- The effects of short-lived climate forcers on climate change are associated with a higher uncertainty than the effects of greenhouse gases such as $CO_2$.

Taking into account these challenges, this paper explores options for addressing non-$CO_2$ emissions as part of the EU 2040 climate target framework.

# 2 Past and projected emissions trends

## 2.1 Trends of methane and nitrous oxide emissions

Trends in emissions of methane and nitrous oxide are shown in Figure 1 and Figure 2, respectively. While emissions from most sectors decreased in the past, only limited reductions are projected for the coming decades.

[6] Regulation (EU) No 517/2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006, http://data.europa.eu/eli/reg/2014/517/oj.
[7] Regulation (EU) 2024/573 on fluorinated greenhouse gases, amending Directive (EU) 2019/1937 and repealing Regulation (EU) No 517/2014, https://eur-lex.europa.eu/eli/reg/2024/573/oj
[8] Directive (EU) 2016/2284 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC, http://data.europa.eu/eli/dir/2016/2284/oj.

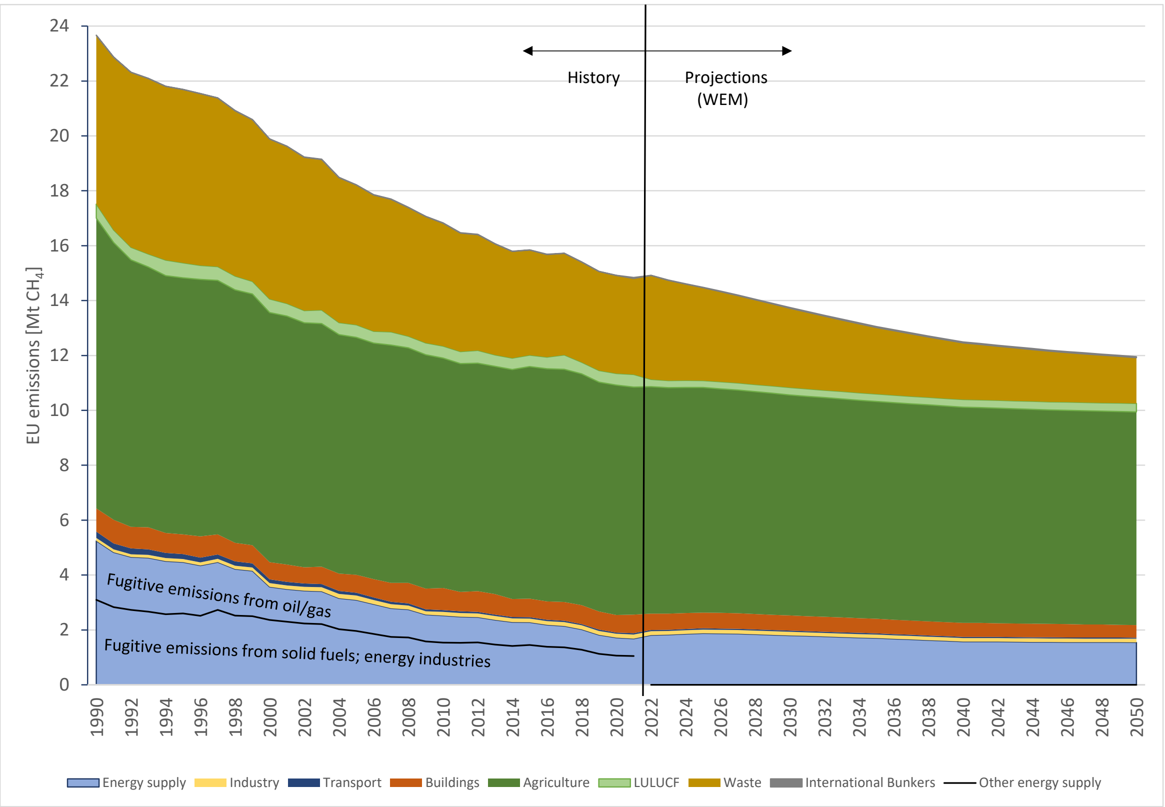


**Figure 1: Past and projected trends of methane emissions in the EU. EEA 2023.**

Note: The distinction between fugitive emissions from oil and gas and other energy supply related emissions is only available for historic data. Projections of methane emissions are only available for the 'with existing measures' scenario.

Sources: European Union. 2023 Common Reporting Format (CRF) Table, https://unfccc.int/documents/627830; EEA greenhouse gas projections - data viewer, https://www.eea.europa.eu/data-and-maps/data/data-viewers/eea-greenhouse-gas-projections-data-viewer

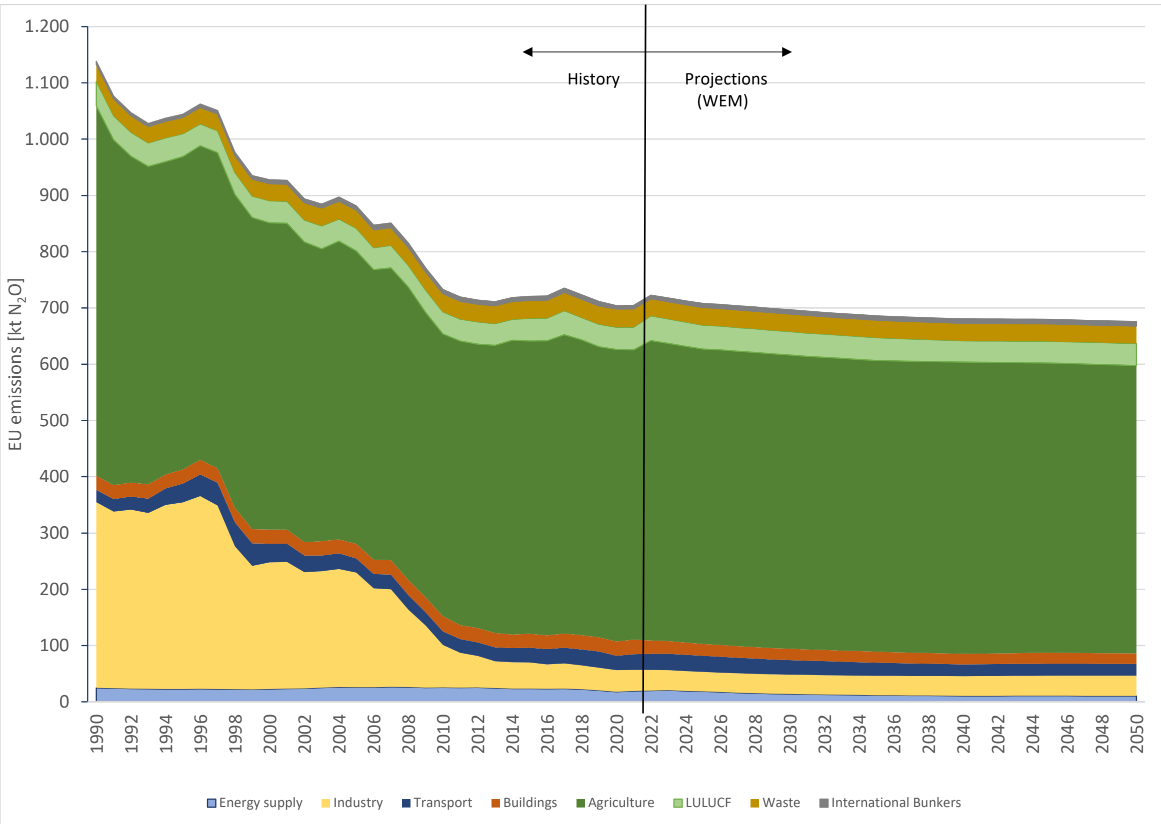


**Figure 2: Past and projected trends of nitrous oxide emissions in the EU. EEA 2023.**

Note: Projections of nitrous oxide emissions are only available for the 'with existing measures' scenario.

Sources: European Union. 2023 Common Reporting Format (CRF) Table, https://unfccc.int/documents/627830; EEA greenhouse gas projections - data viewer, https://www.eea.europa.eu/data-and-maps/data/data-viewers/eea-greenhouse-gas-projections-data-viewer

## 2.2 Trends of various greenhouse gases and climate forcers

Historic annual emissions and projected emissions for some years are available for various other short-lived climate forcers (Figure 3). Emission of F-gases increased after 1990, mainly due to the introduction of hydrofluorocarbons in air conditioning and cooling applications but started to decrease after 2014. Although no inventory of water vapour from aviation is available, emissions can be expected to roughly follow the overall increasing trend of flights and associated $CO_2$ emissions. All other non-$CO_2$ climate forcers showed decreasing emissions after 1990. In the coming years, the emissions of methane and nitrous oxide are projected to decrease slowly only.

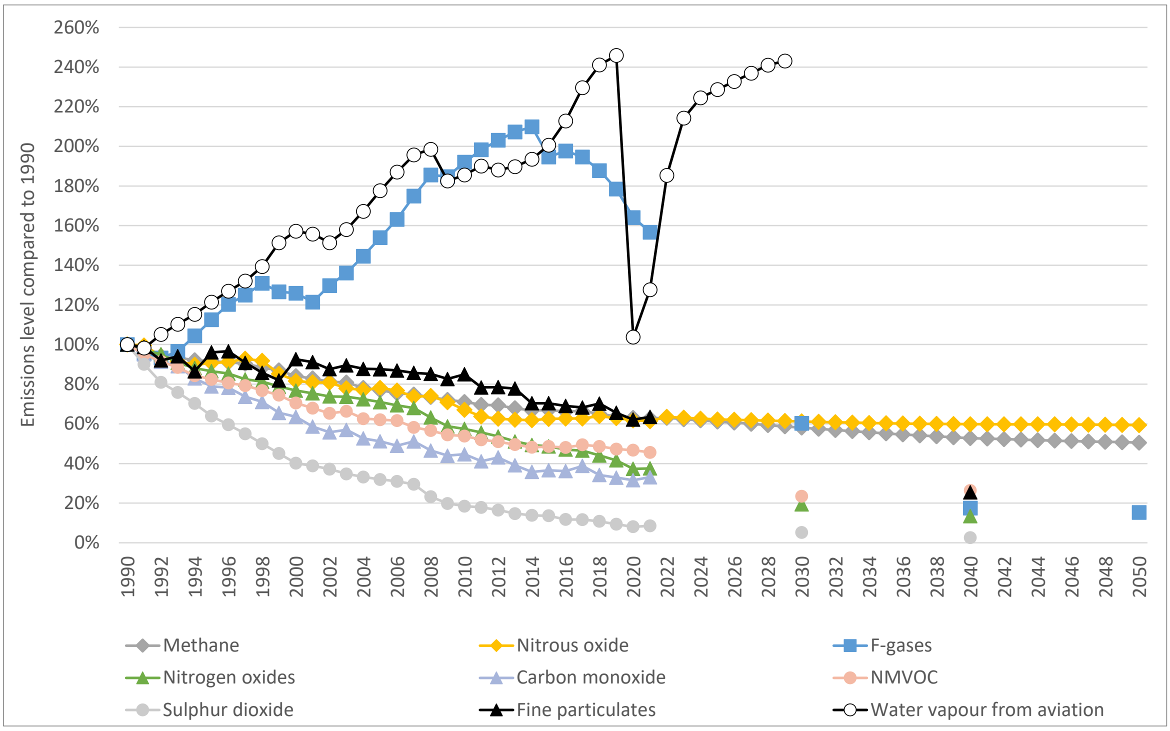


**Figure 3: Past and projected trends of non-$CO_2$ emissions compared to 1990.**

Sources: European Union. 2023 Common Reporting Format (CRF) Table, https://unfccc.int/documents/627830; EEA greenhouse gas projections - data viewer, https://www.eea.europa.eu/data-and-maps/data/data-viewers/eea-greenhouse-gas-projections-data-viewer; EEA air pollutant emissions data viewer, https://www.eea.europa.eu/data-and-maps/dashboards/necd-directive-data-viewer-7; EC (2024); EUROCONTROL 7-year forecast for Europe 2023, https://www.eurocontrol.int/publication/eurocontrol-forecast-update-2023-2029.

Note: Historic water vapour emissions from aviation were approximated by using historic $CO_2$ emissions from international aviation reported in the GHG inventory of the EU. Projected water vapour emissions from aviation were approximated by using the number of flights projected in the EUROCONTROL base scenario.

With the exception of water vapour from aviation, projections of non-$CO_2$ emissions show an overall decrease. Projected methane emissions in the EU decrease slowly only, with agriculture remaining the most important source and accounting for more than two thirds of total methane emissions in the 'with existing measures' scenario in 2050.[9] Similarly, $N_2O$ emissions show modest decreases only, with agriculture remaining the main emission source throughout 2050[10].

In sectors outside agriculture, emissions of $N_2O$ and $CH_4$ are projected to decrease, especially in the energy sector due to decreasing combustion emissions. F-gas emissions continue their decrease until 2050.

For some indirect greenhouse gases, EU-wide projections are available from the impact assessment accompanying the proposal for the 2040 climate target (EC 2024, p. 398). $NO_x$ emissions are projected to decrease by 70% compared to 2005. For NMVOC and $SO_2$, the reduction amounts to 48% and 85%, respectively, between 2005 and 2030. Fine particulate matter ($PM_{2.5}$)

[9] Emissions projection data are available at the EEA data viewer: https://www.eea.europa.eu/data-and-maps/data/data-viewers/eea-greenhouse-gas-projections-data-viewer.

[10] Emissions from the agriculture sector are addressed in the separate paper 'EU 2040 climate Target: Contributions of the agriculture sector'

emissions, a proxy for black carbon emissions, are projected to decrease by 50% over the same period. For carbon monoxide, no emission projections are available at EU level.

Hydrogen emissions are expected to increase considerably with the transition from natural gas to hydrogen as an important fuel in the energy system. According to the impact assessment accompanying the Commission's proposal for the 2040 target (EC 2024), hydrogen production in the EU will increase from 9 million tonnes of oil equivalents (Mtoe) in 2030 to between 60 and 100 Mtoe in 2040 in the various scenarios.

The emissions of water vapour from aviation are expected to increase roughly proportionally to $CO_2$ emissions from the aviation sector. These emissions are projected to continue increasing considerably up to 2050 (e.g., ICAO 2022).

## 2.3 Interplay between gases

In the energy sector, there is interplay between the emissions of several gases. For example, the emissions of methane and nitrous oxide are correlated to $CO_2$ emissions. The emissions of all three gases decrease with a transition away from fossil fuel combustion. Also, with a transition towards hydrogen as a fuel, methane and $CO_2$ emissions decrease, but hydrogen emissions increase.

## 2.4 Key challenges

The challenges in addressing non-$CO_2$ emissions are specific to each substance. In the following, the main challenges are discussed by substance.

### 2.4.1 Methane ($CH_4$)

This section addresses challenges relating to fugitive methane emissions from fuels and methane emissions from the waste sector.[11]

Coal mines are the largest source of fugitive methane emissions in the EU (EEA 2023). There are large differences in emissions between Member States, depending on the occurrence of surface and underground coal mines – both in operation and abandoned. Underground coal mines continue emitting methane for many years after closure. Emitted methane is collected and combusted in some, but not all of these mines.

Fugitive methane emissions also occur alongside gas production, transport and distribution. Leak detection and repair procedures are needed to reduce such emissions. While greenhouse gas inventory data shows that fugitive emissions of methane from the oil and gas sector have declined over the past three decades (EEA 2023), the implementation of additional emission reduction measures is expected to become more costly. Fugitive methane emissions from biogas production will gain importance in the next decade, in light of the EU's increasing production targets. Biogas production facilities present the special challenge of generally being highly decentralized and small-scale.

In the waste sector, the Landfill Directive[12] aims at a progressive reduction of landfilling of waste. However, in many Member States municipal waste with substantial organic contents continues to be landfilled, which leads to continuing methane emissions from landfills.

[11] Emissions from the agriculture sector are addressed in the separate paper 'EU 2040 Climate Target: Contributions of the agriculture sector'

[12] Directive (EU) 2018/850 amending Directive 1990/31/EC on the landfill of waste, http://data.europa.eu/eli/dir/2018/850/oj.

The European waste policies, with their focus on the circular economy, aim at an overall reduction of waste, but they do not particularly address greenhouse gas emissions from the portions of waste that are landfilled. Untreated landfilled waste contributes to methane emissions over time periods of several decades.

### 2.4.2 Nitrous oxide ($N_2O$)

The energy sector is the main source of nitrous oxide emissions outside the agriculture sector. These emissions are related to combustion processes. While a decarbonisation of the energy sector will lead to reduced $N_2O$ emissions from the combustion of fossil fuels, $N_2O$ will continue to be emitted from the combustion of biomass and hydrogen.

$N_2O$ emissions from wastewater (which are part of the waste sector) are a minor, but still relevant category of emissions. While the treatment of wastewater is regulated by the Urban Waste Water Directive [13], this Directive does not specially address the mitigation of $N_2O$ emissions.

### 2.4.3 Water vapour

Non-$CO_2$ effects of aviation contribute to global heating beyond the impact of $CO_2$ alone. The most important driver is induced cloudiness: Under specific atmospheric conditions the emissions of soot and water from airplanes can lead to persistent clouds which – on average – increase global temperatures. While these non-$CO_2$ effects can vary considerably between flights, on average their impact on the climate is 2 to 4 times higher than the impact of aviation related $CO_2$ emissions. In a first approximation, the absolute contribution scales directly with fuel consumption, i.e. it is expected to increase in the future together with rising air travel.

### 2.4.4 Fluorinated gases

The emissions of F-gases increased in the years up to 2014, mainly due to the use of hydrofluorocarbons in cooling and air conditioning. These substances mostly replaced ozone-depleting substances which were phased out under the Montreal Protocol. The trend in F-gas emissions was reversed in recent years after the introduction of legislation that limits the use of certain gases, most notably the F-gas Regulation [14].

### 2.4.5 Hydrogen ($H_2$)

As hydrogen is currently produced and used at a relatively small scale, there is a lack in information on leakage rates across its value chain, and there are uncertainties associated with estimating its direct and indirect radiative effects (Ocko and Hamburg 2022). Due to the importance of hydrogen as a key component of future energy and industrial systems, related data is needed to compare its impacts on climate change to the impacts of alternative energy sources or feedstocks.

In principle, hydrogen can be transported in conventional pipelines, and leaks need to be minimised, detected and repaired similar to leaks in pipelines for natural gas. Due to the different physical properties of hydrogen compared to methane, leakage rates differ and depend on the pipeline material.

[13] Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment, as amended, http://data.europa.eu/eli/dir/1991/271/oj.

[14] Regulation (EU) No 517/2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006, https://eur-lex.europa.eu/eli/reg/2014/517/oj.

### 2.4.6 Other indirect greenhouse gases

Like hydrogen, other indirect greenhouse gases pose challenges as far as monitoring of emissions is concerned. Actual emissions depend on many factors, such as types of combustion processes, technologies, and specific abatement measures in place.

However, emission inventories are available at the EU Member State level and reported under the National Emissions Reduction Commitment Directive[15] and the Convention on Long-range Transboundary Air Pollution[16].

These emission inventories show that overall, the emissions of nitric oxides, carbon monoxide, non-methane volatile organic compounds and sulphur dioxide decreased in recent years. With a future decarbonisation of the energy, industry and transport sectors, emissions of nitric oxides and carbon monoxide will decrease further. However, nitric oxides will continue to be emitted during the combustion of hydrogen, as well as carbon monoxide during the combustion of biomass.

It should be noted that Intergovernmental Panel on Climate Change (IPCC) emission factors for fossil fuels are based on the assumption that all combusted carbon is converted into $CO_2$, rather than a combination of $CO_2$ and carbon monoxide. Hence, these emission factors take into account the indirect effect of carbon monoxide emissions from fossil fuels.

### 2.4.7 Sulphur dioxide

Sulphur dioxide bears the challenge that it has a cooling effect in the atmosphere but has negative effects on health and ecosystems. Its emissions have been regulated successfully in the EU in recent decades, with associated health and ecosystem benefits. As sulphur dioxide can have positive effects on atmospheric cooling but has several negative effects, it is not advisable to include its emissions in the 2040 climate target architecture. Instead, sulphur dioxide emissions are targeted by policies in the area of air pollution control.

### 2.4.8 Black carbon

Emissions of black carbon are more difficult to quantify compared to other substances, because they depend on the parameters of combustion processes, such as temperature and available abatement technologies. Concentrations of black carbon are not routinely measured in exhaust gases; fine particulate matter is sometimes used as a proxy.

In addition, the warming effect of black carbon is not proportional to the amounts emitted, but it depends on where it is deposited – whether on bright surfaces such as snow or on dark surfaces.

For these reasons, the warming effect of black carbon emissions is associated with high uncertainties, which makes it difficult to include them in the 2040 climate target architecture. Nevertheless, existing EU regulations addressing combustion emissions help decrease emissions of black carbon in the future. These include the Industrial Emissions Directive[17], various

---

[15] Directive (EU) 2016/2284 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC, http://data.europa.eu/eli/dir/2016/2284/oj.

[16] European Union emission inventory report 1990-2021 - Under the UNECE Convention on Long-range Transboundary Air Pollution, https://www.eea.europa.eu/publications/european-union-emissions-inventory-report-1990-2021.

[17] Directive 2010/75/EU on industrial emissions (integrated pollution prevention and control), http://data.europa.eu/eli/dir/2010/75/2011-01-06.

Regulations on particulate matter emission standards for vehicles[18] and policies that help reduce overall combustion emissions, such as the EU ETS.

# 3 Sector contributions to the 2040 climate target:

## 3.1 What is already in current legislation?

Non-$CO_2$ emissions are only partially regulated by current EU legislation. In the following, an overview is given of the main elements of the 2030 climate and energy framework and how they address non-$CO_2$ emissions. Other relevant directives and regulations – mostly related to air pollution – are also summarised.

### 3.1.1 EU Emissions Trading System

Besides covering $CO_2$ emissions, the scope of the EU ETS covers emissions of nitrous oxides from the production of nitric, adipic and glyoxylic acids and glyoxal. These continue to be important industrial processes in the EU, but related $N_2O$ emissions have already been abated effectively. In addition, the emissions of specific F-gases, namely perfluorocarbons (PFCs) from aluminium production, are regulated under the EU ETS.

With regards to these emissions, the scope of the EU ETS can be expected to remain similar after 2030. However, it should be noted that the EU ETS for maritime emissions will include methane and nitrous oxide emissions from 2026. Hence, there is a potential to include such emissions from combustion processes outside the shipping sector in the EU ETS in the future. For aviation, airlines need to report on their non-$CO_2$ emissions from 2025 onwards. Based on these reports, the Commission will compile a report and potentially publish a proposal for the inclusion of these emissions into the ETS by the end of 2027. In 2026, the Commission will also assess the feasibility of including municipal waste incineration installations in the EU ETS.[19]

### 3.1.2 Effort Sharing Regulation (ESR)

Most non-$CO_2$ emissions occur in sectors covered by the Effort Sharing Regulation. EU Member States implement a wide range of policies and measures to mitigate such emissions. In addition, these emissions are addressed by other relevant directives and regulations at EU level (cf. section 3.1.4).

### 3.1.3 LULUCF Regulation

The LULUCF Regulation's EU-wide target of -310 million tonnes (Mt) $CO_2e$ net removals by 2030 covers $CO_2$, $CH_4$ and $N_2O$.[20] The reduction of $CH_4$ and $N_2O$ emissions in the LULUCF sector will contribute to the achievement of the net removal target. The main LULUCF sub-

[18] E.g., Commission Regulation (EU) No 459/2012 amending Regulation (EC) No 715/2007 and Commission Regulation (EC) No 692/2008 as regards emissions from light passenger and commercial vehicles (Euro 6), http://data.europa.eu/eli/reg/2012/459/oj.

[19] Consolidated text: Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union and amending Council Directive 96/61/EC, http://data.europa.eu/eli/dir/2003/87/2023-06-05, Article 30(7).

[20] Consolidated text: Regulation (EU) 2018/841 on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry in the 2030 climate and energy framework, http://data.europa.eu/eli/reg/2018/841/2023-05-11.

sector contributing to $CH_4$ emissions is wetlands (1.5% of total EU $CH_4$ emissions in 2021); the main contributor to $N_2O$ emissions is forest land (2.6% of total EU $N_2O$ emissions in 2021).

### 3.1.4 Other relevant directives or regulations

Methane emissions in the waste sector are addressed by the Landfill Directive[21]. Concerning emissions in the energy sector, the Methane Regulation[22] lays down the rules for monitoring, reporting and verification of methane emissions from oil, gas and coal, and for abating these emissions.

There is no overarching EU policy specifically addressing nitrous oxide emissions from the agriculture sector. The same is true for the energy sector, but $N_2O$ emissions are reduced through the implementation of policies that aim at reducing emissions from combustion processes, such as the EU ETS or $CO_2$ standards for road transport[23]. While the treatment of wastewater is regulated by the Urban Waste Water Directive[24], this directive does not specially address the mitigation of $N_2O$ emissions.

The emissions of F-gases have been reduced recently through the implementation of the F-gas Regulation[25], and further emission reductions will follow from the implementation of its latest revision[26].

The emissions of $NO_x$, NMVOC, $SO_2$ and fine particulate matter (which is related to black carbon) are addressed by the National Emissions Reduction Commitments Directive[27]. Additional EU regulations addressing combustion emissions help further decrease these emissions in the future. These include the Industrial Emissions Directive[28], various regulations on particulate matter emission standards for vehicles[29] and policies that help reduce overall combustion emissions, such as the EU ETS.

## 3.2 Possible range of emissions in 2040 – with a glimpse on 2050

In sectors other than agriculture, the emissions of non-$CO_2$ greenhouse gases are projected to decrease substantially in the coming decades (Figure 4). Notably, F-gas emissions will decrease by approximately 90% by 2040 compared to 2015.

By 2050, the emissions of these non-$CO_2$ gases will be reduced further. Remaining emissions include methane and nitrous oxide from energy, transport and waste/wastewater, as well as F-gases and $N_2O$ from industrial processes and product use.

[21] Directive (EU) 2018/850 amending Directive 1990/31/EC on the landfill of waste, http://data.europa.eu/eli/dir/2018/850/oj.
[22] Regulation (EU) 2024/1787 on methane emissions reductions in the energy sector and amending Regulation (EU) 2019/942, https://eur-lex.europa.eu/eli/reg/2024/1787/oj.
[23] Such Emissions from the energy sector are addressed in the separate paper 'EU 2040 Climate Target: The Role of Energy'.
[24] Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment, as amended, http://data.europa.eu/eli/dir/1991/271/oj.
[25] Regulation (EU) No 517/2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006, http://data.europa.eu/eli/reg/2014/517/oj.
[26] Regulation (EU) 2024/573 on fluorinated greenhouse gases, amending Directive (EU) 2019/1937 and repealing Regulation (EU) No 517/2014, https://eur-lex.europa.eu/eli/reg/2024/573/oj.
[27] Directive (EU) 2016/2284 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC, http://data.europa.eu/eli/dir/2016/2284/oj.
[28] Directive 2010/75/EU on industrial emissions (integrated pollution prevention and control), http://data.europa.eu/eli/dir/2010/75/2011-01-06, as amended.
[29] E.g., Commission Regulation (EU) No 459/2012 amending Regulation (EC) No 715/2007 and Commission Regulation (EC) No 692/2008 as regards emissions from light passenger and commercial vehicles (Euro 6), http://data.europa.eu/eli/reg/2012/459/oj.

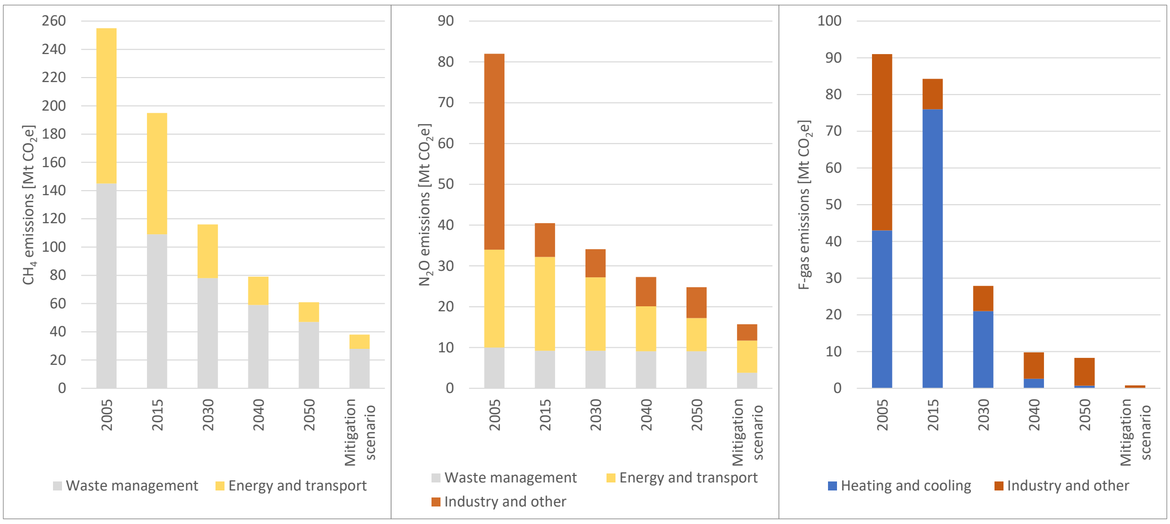


**Figure 4: Non-$CO_2$ greenhouse gas emissions in non-land sectors**

Source: (EC 2024), pages 358 to 364.

Note: The 'mitigation scenario' in the figure corresponds to a combination of scenarios S1, S2, S3 and LIFE modelled as part of the impact assessment.

## 3.3 Differences between Member States

The trends in emissions of non-$CO_2$ gases differ between Member States, depending on factors such as main energy sources and waste management practices. Figure 5 shows changes in emissions by Member State for two categories which are of most interest here: methane emissions from the waste sector, and methane emissions from energy supply. In both categories, several Member States already achieved substantial emission reductions in the past. These can serve as a model for Member States with less pronounced decreases or historic increases.

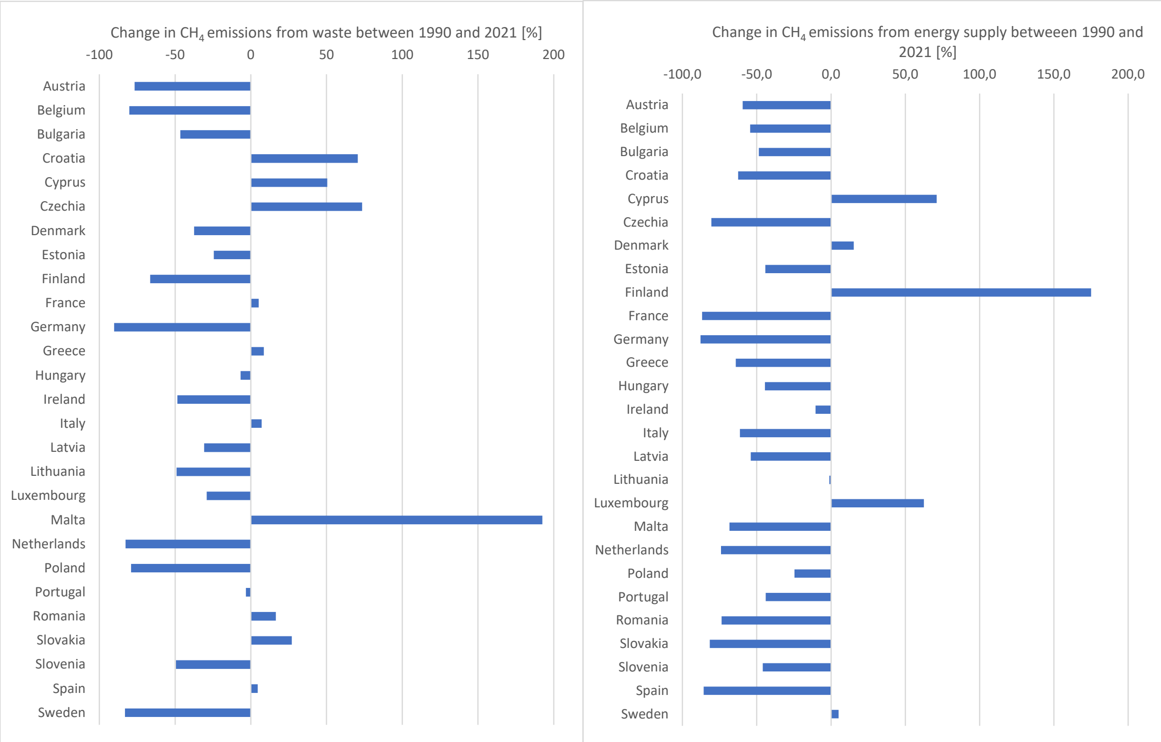


**Figure 5: Change in methane emissions between 1990 and 2021 per Member State: Waste sector (left) and energy sector (right)**

Source: EEA greenhouse gas projections - data viewer, https://www.eea.europa.eu/data-and-maps/data/data-viewers/eea-greenhouse-gas-projections-data-viewer

In the waste sector, several Member States in central and northern Europe achieved substantial methane emission reduction by reducing the amount of landfilled waste (e.g., German Environment Agency 2023). In several Member States that joined the EU in 2004 or later, the volume of landfilled waste, and hence methane emissions, still increased in recent decades.

In the energy supply sector, methane emissions decreases substantially in most Member States, due to mine gas collection and leak reduction in gas supply systems (e.g., German Environment Agency 2023). The increase in some Member States is due to changes in the energy supply system, such as an important extension of the natural gas supply network (Statistics Finland 2023).

# 4 How to achieve the necessary contribution: Discussion of possible policies and measures and options

As discussed above, the reduction of non-$CO_2$ emissions poses challenges because these emissions are spread across a wide range of sources and their quantification is associated with high uncertainties. Nevertheless, existing EU policies could be strengthened, and new policies introduced to help reduce these emissions. In this chapter, possible additional polices are discussed for the various non-$CO_2$ climate forcers.

## 4.1 Policies and measures addressing methane

### 4.1.1 Strengthen regulations for methane emissions in the energy sector

As far as fugitive emissions of methane from the energy infrastructure are concerned, the recently adopted Methane Regulation contains new measurement and reporting provision and rules to detect and repair methane leaks and to limit venting and flaring, within the EU as well as for imports. The emissions addressed by the Methane Regulation are part of the effort sharing sectors, i.e., the implementation of this regulation helps achieve the effort sharing targets for 2030 and contributes to emission reductions beyond 2030. At the international level, the European Union and over 150 countries agreed under the 'Global Methane Pledge' to contribute to a collective effort to reduce global methane emissions at least 30 percent from 2020 levels by 2030.[30]

The question arises whether a separate target for methane emissions from the energy sector should be envisaged for 2040. Given the relatively small contribution of these emissions to overall methane emissions within the EU, a separate target may not be effective. With the expected decarbonisation of the energy system, i.e., the phase-down of fossil fuels such as coal and natural gas by 2040, methane emissions from these fuels will also decrease.

The EU ETS or other carbon pricing instruments could possibly complement the regulatory actions taken under the Methane Regulation. However, fugitive emissions from energy infrastructure are hard to measure and are associated with high uncertainties, which in the past has made it difficult to include them in a carbon pricing mechanism. The increasing application of best-practice monitoring methods under the Methane Regulation, and under the EU ETS for maritime emissions can provide opportunities for introducing a pricing instrument for methane emissions in the future.

### 4.1.2 Address methane emissions from biogas

In the REPowerEU Plan, the EU set its ambitions high on biomethane production, targeting a yearly production of 35 billion cubic metres by 2030. However, there is a clear regulatory gap around methane leakage from biogas production. The recently adopted Methane Regulation does not cover biogas production, and the sustainability criteria of the revised Renewable Energy Directive (Article 29) do not include methane-relevant aspects.

Biogas and upgraded biomethane, as a direct substitute for natural gas, have significant potential for GHG emission reduction and supporting a shift towards a circular economy. In the waste sector, the methanization of biowaste can lead to a reduction of methane emissions that are otherwise difficult to reduce. In the agricultural sector, using the remaining digestate as natural fertilizer can reduce $N_2O$ emissions and manure methanization can reduce methane emissions. Still, a rapid upscaling of biogas production comes with great challenges, especially regarding methane leakage and greenhouse gas emissions from land use change.

Methane leakage from biogas production facilities, as well as transmission and upgrading infrastructure, pose a significant risk for unmonitored increase of non-$CO_2$ emissions. The risk of leakage is particularly significant during the steps preceding the upgrading and injection into existing gas networks. Not covered by the Methane Regulation, these emissions occur in a context specific for biogas installations, which are usually small-scale, highly decentralized, and with a lower level of industrialization or technical deployment. Even if it is a great challenge, the ambition must be to reduce leakage to a minimum, e.g., following the example of Denmark with

[30] Global Methane Pledge, https://www.globalmethanepledge.org.

recent policies in place requiring monitoring, reporting, and verification (MRV), as well as fixing leaks to a maximum of 1% leakage from 2025 in all biogas plants [31].

Leakage can be reduced by using appropriate technologies in the upgrading process, like chemical scrubbing instead of exhaust gas treatment (Wechselberger et al. 2023), or through applying relatively simple technical mitigating actions, like renewed pressure-relief valves (Fredenslund et al. 2023). Still, proper MRV strategies at small-scale installations remain a major challenge. Current measurement approaches include on-site and ground-based remote sensing (Reinelt et al. 2017). Deployment of MRV technologies would need to be included in national biogas strategies and support for investments is needed, especially for small-scale installations.

The resulting emissions and environmental risks regarding biogas fundamentally depends on the type of feedstock used for its production. While the use of feedstock like livestock manure or urban, agricultural, as well as landfilled waste has the potential to reduce GHG emissions overall, using feedstock like primary food crops or forest biomass comes with the risk of having an overall negative impact regarding land pressure, GHG emissions, and environmental degradation. If only feedstock like biowaste or, especially, manure is used, the impact of possible methane leakage would be considerably smaller compared to a situation where waste or manure are not converted into biogas.

Therefore, it must be central to an EU biogas strategy to focus on sustainable feedstock and ensure that biogas production from primary food and energy crops is reduced to an absolute minimum, e.g., by setting a ceiling for the share of unsustainable feedstock in coherence with the criteria of the revised Renewable Energy Directive. A better mobilization of manure and biowaste as feedstock needs to be incentivized, for example through concrete conversion targets. Appropriate measures to achieve the targets could be to couple biogas subsidies and feed-in tariffs to feedstock origin. These measures should be complemented by improved leakage monitoring and prevention.

### 4.1.3 Provide incentives for methane emission reductions in the waste sector

Despite an overall reduction of landfilled waste due to the implementation of the Landfill Directive, landfills continue to be an important source of methane emissions. Currently, there is a lack of incentives to further reduce the amount of landfilled organic waste, and to mitigate emissions from landfills.

Methane emissions from landfills could be included in the scope of the EU ETS. Landfill operators could be required to retire allowances for emissions generated in their landfills. This requirement would constitute an incentive to recover methane emissions from landfilled waste, to pre-treat waste before it is landfilled, and to foster alternative waste management measures, including the reduction of organic waste, composting and waste incineration.

According to Article 30(7) of the revised ETS Directive [32], the European Commission shall present a report by 31 July 2026 in which it shall assess the feasibility of including municipal waste incineration installations in the EU ETS. In the same report, ‘the Commission shall also assess the possibility of including in the EU ETS other waste management processes, in particular landfills’.

As an alternative to the EU ETS, the landfilling of organic waste could be subject to a levy, which would also constitute an incentive to reduce the landfilling of such waste.

[31] Denmark draft NECP 2023, p.125

[32] Consolidated text: Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union and amending Council Directive 96/61/EC, http://data.europa.eu/eli/dir/2003/87/2023-06-05, Article 30(7).

However, the pricing of methane emissions from the waste sector poses various challenges. First, the amount of emissions per unit of landfilled waste varies considerably, depending on its composition and any mitigation measures in place at the landfill. Data on waste composition is scarce in many cases and associated with uncertainties. Methane emissions from landfills can only be measured punctually and with uncertainties. In addition, landfills continue to emit methane for decades after waste has been disposed. A pricing mechanism for waste disposal does not necessarily address these emissions.

Besides a pricing mechanism, improved regulations can help reduce methane emissions from the waste sector. These regulations could include a ban on the landfilling of untreated organic waste and improved pre-treatment with provisions to minimise methane emissions. In order to be able to identify the main remaining emission sources, it is important to use specific emission factors, rather than default emission factors for waste streams.

While waste incineration generates $CO_2$ emissions and the amount of waste incinerated needs to be minimised, the incineration of household waste for energy use can help replace fossil fuels, while reducing the amount of waste landfilled.

## 4.2 Policies and measures addressing nitrous oxide

As mentioned in chapter 1, the agriculture sector accounts for almost three quarters of all nitrous oxide emissions in the EU.[33] Emissions from the energy sector amount to 12% of total EU nitrous oxide emissions. As these are associated with combustion processes, they will be reduced alongside $CO_2$ emissions from the combustion of fossil fuels.

However, nitrous oxide continues to be emitted during the combustion of non-fossil fuels such as hydrogen and biomass. This has to be taken into account under further policies targeting these non-fossil fuels.

Nitrous oxide emissions from the waste sector, which account for 5% of total $N_2O$ emissions, are not explicitly addressed by the Urban Wastewater Treatment Directive. However, the Commission's proposal for a revision of this directive[34] contains provisions for additional treatment of nitrogen, which is expected to result in substantial $N_2O$ emission reductions.

## 4.3 Policies and measures addressing fluorinated gases

With the recently adopted revised F-gas Regulation, the emissions of fluorinated gases are expected to continue to decrease beyond 2030. The revised F-gas Regulation[35] requires stepwise reductions of EU-wide HFC supply, including a -95 % reduction compared to 2015 by 2030 and a complete HFC phase-out by 2050. Furthermore, it sets out a series of specific bans entering into force between 2025 and 2035, like on HFC use in various refrigeration, air-conditioning and heat pump equipment categories and on $SF_6$ use in electrical equipment categories. With this revision, no major emission sources will remain which are not addressed within the EU. According to the impact assessment accompanying the Commission's proposal for the 2040 target (EC 2024), F-gas emissions in 2040 will be 90% below 2015 levels.

---

[33] Emissions from the agriculture sector are addressed in the separate paper 'EU 2040 climate Target: Contributions of the agriculture sector'

[34] Proposal for a Directive concerning urban wastewater treatment (recast), COM/2022/541 final, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2022%3A541%3AFIN

[35] Regulation (EU) 2024/573 on fluorinated greenhouse gases, amending Directive (EU) 2019/1937 and repealing Regulation (EU) No 517/2014, https://eur-lex.europa.eu/eli/reg/2024/573/oj.

## 4.4 Policies and measures addressing water vapour

A set of policies could be used to reduce non-$CO_2$ effects from aviation. Cloud formation only occurs under specific atmospheric conditions. Flights can be rerouted to circumvent such zones. This could be achieved either by regulation or by putting a price on non-$CO_2$ effects as might happen under the EU ETS. Using alternative fuels and especially e-fuels also has a positive effect: these fuels have lower sulfur content and therefore produce less soot when combusted. Any measures that reduce demand for aviation would automatically also reduce the effects of the associated non-$CO_2$ emissions. These measures could be economic, such as higher carbon prices or ticket taxes, but also regulatory, such as reducing the number of landing slots in an airport.

## 4.5 Policies and measures addressing hydrogen emissions

Fugitive emissions from hydrogen distribution networks can be reduced by measures that are similar to those addressing methane emissions from natural gas networks. However, in order to be able to quantify the mitigation potential, additional research on hydrogen emissions along the whole value chain is needed.

## 4.6 Policies and measures addressing other climate forcers

The climate forcers $NO_2$, CO, NMVOC, $SO_2$ and black carbon are either addressed by air pollution legislation, or their emissions are projected to decrease further due to a transition away from combustion processes. In addition, the warming effect of these climate forcers is associated with higher uncertainties compared to greenhouse gases.

Hence, the emissions of these substances should not be specifically included under the 2040 target, but they should continue to be addressed by specific air pollution legislation.

## 4.7 Conclusions

With the reduction of $CO_2$ emissions in the EU in the period up to 2040, non-$CO_2$ emissions gain in importance. In the sectors outside agriculture, these include fugitive emissions of methane from energy systems and methane emissions from landfills. While the recently agreed Methane Regulation helps reduce fugitive emissions from natural gas, oil and coal, fugitive emissions from biogas production and distribution may increase in the future. The emissions of the indirect greenhouse gas hydrogen, and of water vapour from aviation, are also projected to increase. As these and other non-$CO_2$ emissions come with higher uncertainties compared to $CO_2$, targeted regulations, rather than pricing mechanisms, are the first choice for helping reduce these emissions with a time horizon up to 2040.

# References

EC - European Commission (ed.) (2024): Impact Assessment Report, Accompanying the document "Communication from the Commission to the EU. Securing our future Europe's 2040 climate target and path to climate neutrality by 2050 building a sustainable, just and prosperous society" (SWD(2024) 63 final). European Commission. Strasbourg, 2024. Online available at https://climate.ec.europa.eu/document/download/768bc81f-5f48-48e3-b4d4-e02ba09faca1_en?filename=2040%20Climate%20Target%20Impact%20Assessment_en_0.pdf, last accessed on 20 Feb 2024.

EEA (2023): European Union. 2023 Common Reporting Format (CRF) Table, 2023. Online available at https://unfccc.int/documents/627830, last accessed on 23 Jul 2024.

Fredenslund, A. M.; Gudmundsson, E.; Maria Falk, J.; Scheutz, C. (2023): The Danish national effort to minimise methane emissions from biogas plants. In: *Waste Management* 157, pp. 321–329. DOI: 10.1016/j.wasman.2022.12.035.

German Environment Agency (2023): National Inventory Report for the German Greenhouse Gas Inventory 1990-2021. German Environment Agency (ed.), 2023. Online available at https://unfccc.int/documents/627785, last accessed on 29 Mar 2024.

ICAO - International Civil Aviation Organization (2022): Report on the feasibility of a long-term aspirational goal (LTAG) for international civil aviation CO2 emission reductions, ICAO committee on aviation environmental protection, 2022. Online available at https://www.icao.int/environmental-protection/LTAG/Pages/LTAGreport.aspx, last accessed on 4 Aug 2022.

Ocko, I. B.; Hamburg, S. P. (2022): Climate consequences of hydrogen emissions. In: *Atmos. Chem. Phys.* 22 (14), pp. 9349–9368. DOI: 10.5194/acp-22-9349-2022.

Reinelt, T.; Delre, A.; Westerkamp, T.; Holmgren, M. A.; Liebetrau, J.; Scheutz, C. (2017): Comparative use of different emission measurement approaches to determine methane emissions from a biogas plant. In: *Waste Management* 68, pp. 173–185. DOI: 10.1016/j.wasman.2017.05.053.

Statistics Finland (2023): Finland. 2023 Common Reporting Format (CRF) Tables. Statistics Finland (ed.), 2023. Online available at https://unfccc.int/documents/627719, last accessed on 29 Mar 2024.

Wechselberger, V.; Reinelt, T.; Yngvesson, J.; Scharfy, D.; Scheutz, C.; Huber-Humer, M.; Hrad, M. (2023): Methane losses from different biogas plant technologies. In: *Waste Management* 157, pp. 110–120. DOI: 10.1016/j.wasman.2022.12.012.

**Ecologic Institute**

**www.ecologic.eu**

**FB:** /Ecologic.Institute

**Twitter:** /EcologicBerlin

**Öko-Institut**

**www.oeko.de**