Denmark's Climate Status and outlook 2023

Danish Energy Agency

Denmark's Climate Status and Outlook, 2023

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1 About Denmark's Climate Status and Outlook 2023

Denmark's Climate Status and Outlook 2023 (CSO23) is an account of how Danish greenhouse gas emissions have developed from 1990 to 2021, as well as an assessment of how, with the assumptions set out, greenhouse gas emissions as well as energy consumption and production will evolve over the period up to 2035 in a frozen-policy scenario.

This frozen-policy scenario describes a scenario in which no new policy measures are introduced in the climate and energy area other than those decided by the Danish Parliament or the EU before 1 January 2023, or arising out of binding agreements. The policy freeze pertains to Danish and EU climate and energy policy only, and it does not reflect the assumption that developments in general will come to a halt. For example, economic growth and demographic trends are not part of the freeze.

CSO23 thus serves to describe to what extent Denmark's climate and energy targets and obligations are expected to be met within the framework of current regulation.

1.1 What is the basis for CSO23?

Pursuant to the Danish Climate Act of 18 June 2020 (the Climate Act) a climate status and outlook report must be drawn up annually.[1]

The Climate Act stipulates that Denmark is to reduce emissions of greenhouse gases by 50-54% by 2025 and 70% by 2030 relative to the 1990 level. Furthermore, the Climate Act requires the Minister for Climate, Energy and Utilities to prepare an annual climate status and outlook report (CSO).

The climate and status report is part of an annual cycle prescribed in the Climate Act. The purpose of the annual cycle is to ensure annual follow-up on whether Danish climate action is supporting fulfilment of the targets set out in the Climate Act. According to the annual cycle, each year in April, the annual CSO report is to review Denmark's progress toward meeting its climate targets.

[1]The Climate Act also requires global reporting on the international impacts of Danish climate action. Annual global reporting for 2023 has been prepared and published as a separate publication in parallel with CSO23. References to CSO23 therefore only pertain to the national climate status and outlook report.

1.2 What does CSO23 include and how are the climate projections made?

To understand the results in CSO23, it is important to know what emissions are covered in the underlying climate projections, what policy measures, etc. are included, and how the projections are made.

What emissions are included in CSO23?

The Climate Act sets out targets for greenhouse gas emissions reductions as well as guidelines for how these should be calculated. As a rule, the reduction targets for greenhouse gas emissions should be met within Danish territory, and the greenhouse gas emissions included in the targets set out in the Climate Act should be calculated using the UN IPCC methodology. The targets in the Climate Act include Denmark's overall greenhouse gas emissions, including carbon removals/emissions by soils and forests (LULUCF), negative emissions from technological processes (e.g. underground storage of CO_2) and indirect CO_2 emissions (substances that, at a later stage, are converted to CO_2 in the atmosphere).[2]

What policy measures etc. are included CSO23?

The cut-off date for including policy measures in CSO23's modelling for the period 2022 to 2035 has been set at 1 January 2023. The cut-off date for including policy measures in CSO22 was 1 January 2022. The new policy measures included in CSO23 include measures under the *green tax reform for industry etc. agreement*, the *climate agreement on green power and heating,* and the *mileage-based road tax on heavy-duty vehicles agreement*. For a full list of the new policy measures included in CSO23, see chapter 2 of the CSO23 memorandum on sector assumptions on principles and policies. This chapter also contains a list of the measures that have not been included in CSO23, either because they have yet to be sufficiently concretised or because it is currently not possible to estimate their effect.

How was CSO23 prepared?

CSO23 is a collection of a number of different projections from the Danish Energy Agency and the Danish Centre for Environment and Energy (DCE), which the Danish Energy Agency has combined with statistical data to produce an overall climate status and outlook report for Denmark. How CSO23 was prepared is described in more detail in the CSO23 memorandum on assumptions titled *Introduction to CSO23 assumptions material*, and the specific assumptions, data and models used in the projection of emissions, etc. are described in the various other CSO23 memoranda on sector assumptions.

[2]In accordance with the UN IPCC methodology, the targets do not include emissions from international shipping and aviation, nor do they include direct emissions of CO_2 from burning biomass (wood chips and wood pellets, for example, i.e., biogenic CO_2 emissions). See chapter 3 on principles and policies in the CSO23 memorandum on sector assumptions for further explanation of the emissions covered in CSO23.

1.3 What uncertainty is linked to CSO23?

It is important to bear in mind that sensitive assumptions and uncertainties affect the key results in CSO23. Other assumptions than those applied would therefore lead to other results. The projections look more than ten years ahead, and the results may vary from year to year, regardless of measures. The projected results are therefore subject to general methodological uncertainty and to considerable uncertainty due to external variables, including unforeseen developments in preferences and behaviour, technologies and prices as well as fluctuations in weather, etc. The uncertainties associated with projected results for the individual sectors are described in the respective chapters about these sectors, as well as in the associated sector memoranda.

1.4 How is the CSO23 material structured?

CSO23 consists of a main report, underlying sector memoranda and memoranda of sector assumptions, as well as a number of data sheets. For each of the main report's sector chapters (chapters 3-11), one or several sector memoranda have been prepared presenting detailed and thoroughly documented status descriptions and projections for the sector in question. Furthermore, the assumptions underlying the projections have been documented in several memoranda on sector assumptions. These memoranda were subject to public consultation in January 2023.

In addition to the main report and the sector memoranda, CSO23 has been supplemented with a series of data sheets, e.g. on CRF tables, energy balance and additional sector data. Data for indicators listed in the *2020 Climate Action Plan* is presented in Appendix 5.2 in the relevant sector memoranda.[3]

[3] The 2020 Climate Action Plan presents several indicators which will in future contribute to the assessment of progress in the transition of individual sectors.

2 The overall picture

Denmark's **climate status**: In 2021, total greenhouse gas emissions, including soil and forest emissions and removals[4], came to 46.2 million tonnes CO_2e.[5] This means that, in 2021, Danish greenhouse gas emissions had been cut by 41% compared to total Danish emissions in 1990. Note that the Covid-19 pandemic continued to have an effect on activity levels in some sectors in 2021, including on energy consumption and greenhouse gas emissions by these sectors.

Denmark's **climate outlook**: Based on current adopted policies, total net emissions[6] are projected to fall to 39.7 million tonnes CO_2e by 2025 and to 28.9 million tonnes CO_2e by 2030. This corresponds to a reduction in emissions of 49.3% and 63.1%, respectively, compared to 1990. By 2035, total net emissions are expected to have been reduced additionally to 25.8 million tonnes CO_2e.[7]

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[4] I.e. LULUCF, Land Use, Land-Use Change and Forestry.

[5] After recognition of the expected effect of bio-covers.

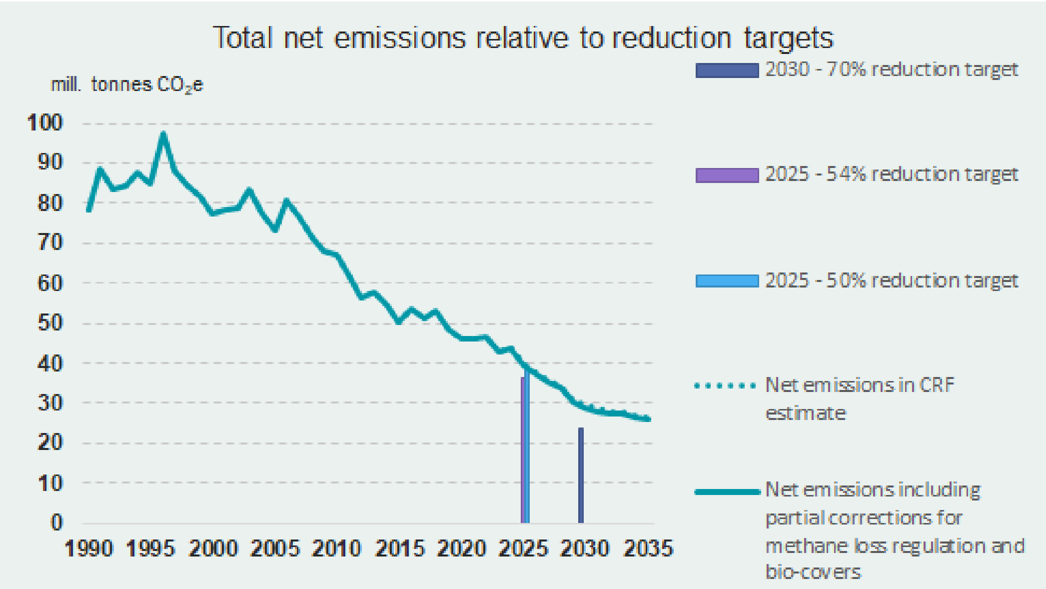
[6] 'Total net emissions' refers to total emissions (including LULUCF), and after recognition of CCS.

[7]These estimates of net emissions include recognition of corrections for the expected effect of methane loss regulation and bio-covers. As explained later in the report, the expected effect of methane loss regulation and bio-covers cannot be included in the CRF estimates at this point. Before recognition of partial corrections for the impact of methane loss regulation and bio-covers, the CRF estimates therefore show net emissions of 40.2 million tonnes CO_2e by 2025 and 29.5 million tonnes CO_2e by 2030 (see also appendix 5 on the calculation of net emissions including partial corrections for methane loss regulation and bio-covers on the basis of the CSO23 CRF estimate).

Naturally, projections in Denmark's climate status and outlook reports are linked to uncertainty, and this uncertainty is particularly pronounced at the moment, with the Covid-19 pandemic influencing emissions in the two most recent historical calculation years, 2020 and 2021.[8] Furthermore, energy markets are characterised by uncertainty, and this uncertainty will influence energy prices and energy consumption in the future. The possible permanent effects of the above on such things as consumer behaviour, structural aspects and choice of technology are not reflected in this year's projection.

The projected development in net emissions and the emissions gap relative to the reduction targets for 2025 and 2030 are illustrated in figure 2.1.

Figure 2.1: Total net emissions and reduction targets for 2025 and 2030



Note: Total CSO23 net emissions include recognition of a statistical difference on historical figures to ensure consistency with official data from the Danish Centre for Environment and Energy (DCE).

2.1 Status of progress towards the reduction targets set out in the Climate Act

The *climate agreement on green power and heating* introduced a regulation scheme for methane losses from biogas plants. The scheme entered into force on 1 January 2023. The expected effect of the methane loss regulation scheme has not been included in the CSO23 CRF estimates due to the calculation principles applied by the Danish Centre for Environment and Energy (DCE). However, as set out in the *2022 climate agreement on green power and heating*, the expected effect has been included in the emissions gap estimates for 2025 and 2030, and the effect has also been recognised in the emissions gap estimate for the EU effort sharing obligation, etc. Furthermore, the

[8] Although 2021 is the most recent statistical year, model runs for CSO23 sometimes use emissions from 2019, as activity levels in this year are assumed to be a more representative basis.

expected effect of bio-covers has been partially recognised in the CSO23 emissions gap estimates, etc.[9]

Recognising the partial corrections for the expected effect of regulation concerning methane leaks from biogas plants and bio-covers leads to a CSO23 emissions gap of 0.5-3.7 million tonnes CO_2e for the Climate Act's indicative target to reduce emissions by 2025 by 50-54% compared to 1990, and an emissions gap of 5.4 million tonnes CO_2e for the target to reduce emissions by 2030 by 70% compared to 1990.

The funds in the first phase of the CCUS pool were awarded to Ørsted on 15 May 2023 (i.e. after CSO23 was submitted for public consultation on 28 April). It is expected that Ørsted will be able to store 0.034 million tonnes of CO_2 in 2025, and 0.43 million tonnes CO_2 per year after this time. These quantities have been included in the estimate of total net emissions and in the estimate of the emissions gap in the final version of CSO23. Note that, apart from the above, there have been no further changes with regard to the recognition of CCS in the final version relative to the consultation version of CSO23. That is, in both versions, CCS has been dealt with as negative emissions not broken down by sector. The CCUS pool is therefore not included in the emissions estimate for the electricity and district heating sector, but has instead been included in the total CCS contribution in the emissions estimate.

Table 2.1: Status of progress towards the reduction targets set out in the Climate Act

	1990	2021	2025	2030	2035
CSO22 total net emissions (million tonnes CO_2e)	78.0	45.5	41.4	33.6	30.2
CSO23 total net emissions including partial corrections*	**78.4**	**46.2**	**39.7**	**28.9**	**25.8**
Climate Act reduction target compared to CSO23 (million tonnes of CO_2e)			36.1-39.2	23.5	
Emissions gap between CSO23 and reduction targets (million tonnes CO_2e)			**0.5-3.7**	**5.4**	

Note: Emissions in target years and the remaining emissions gap have been calculated as annual values in the table.

* See Appendix 5 for the calculation of CSO23 net emissions including partial corrections for methane loss regulation and bio-covers on the basis of CSO23 CRF calculations.

The estimate of target year emissions and the associated emissions gap assumes that all projection years are 'normal years' and, similarly, projected emissions from soils represent a weighted normal level. However, pursuant to the Climate Act, observed emissions relative to reduction targets in both 2025 and 2030 must be calculated as

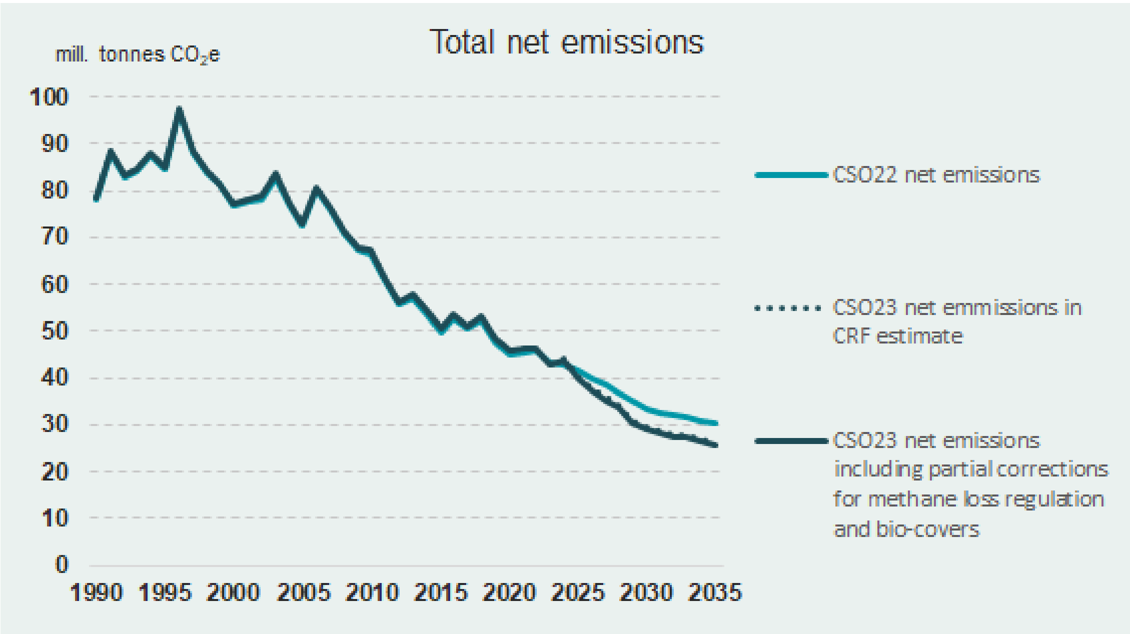
[9] For more about the partial correction regarding regulation of methane losses from biogas plants, see chapter 2 in the CSO23 memorandum on sector assumptions on principles and policies and CSO23 sector memorandum 7B on Biogas, PtX and renewable fuels. For more about the partial correction regarding bio-covers, see the CSO23 memorandum on assumptions on other waste and wastewater.

three-year averages to minimise the significance of fluctuations in individual years (caused by weather fluctuations, for example).

Comparison with CSO22

A comparison with last year's Climate Status and Outlook (CSO22) shows minor fluctuations in total net emissions in the first years, most pronouncedly in 2024 with an increase in emissions of 0.7 million tonnes CO_2e (partly due to fuel consumption by the electricity and district heating sector). As can be seen from figure 2.2, CSO23 emissions are estimated to be lower than CSO22 emissions from 2025 and onwards. CSO23 estimates emissions in 2025 to be at around 1.7 million tonnes CO_2e below the level estimated in CSO22, and this difference widens so that, by 2027, CSO23 emissions are estimated to 3.1 million tonnes CO_2e below the level estimated in CSO22. From 2029 and onwards, the difference between CSO22 and CSO23 emissions widens further so that, by 2035, CSO23 emissions are estimated at around 4.5 million tonnes CO_2e below the level estimated in CSO22. This difference is partly because CSO23 assumes that the CCS pool under the *green tax reform* will have been fully phased in by 2029 and will therefore contribute with carbon capture of 1.8 million tonnes of CO_2 annually.

Figure 2.2: Comparison of total net emissions in CSO23 and CSO22



The emissions gap towards the 2025 target has been reduced by around 1.7 million tonnes CO_2e compared with CSO22, while the emissions gap towards the 2030 target has been reduced by around 4.7 million tonnes CO_2e compared with CSO22.

Comparison with the government's 2022 Climate Programme

The government's 2022 Climate Programme estimated the emissions gap in 2025 to be 0.4-3.5 million tonnes CO_2e and the emissions gap in 2030 to be 5.0 million tonnes CO_2e. These estimates included the CSO22 estimate as well as the partially estimated impacts of 1) the *green tax reform for industry etc. agreement*, 2) the *mileage-based* *road tax on heavy-duty vehicles agreement*, and 3) the *climate agreement on green power and heating*. The emissions gap in 2025 is therefore around 0.3 million tonnes CO_2e wider compared with the government's 2022 Climate Programme, and the emissions gap in 2030 is around 0.5 million tonnes CO_2e wider than the 2022 Climate Programme.

2.2 Developments in framework conditions etc. since CSO22

The development in emissions is the result of a combination of new policy measures (national and EU measures), updated expectations about price and market developments, and an updated data basis. Furthermore, the methodological approach has also been updated in some areas, and this may have influenced the result.

New national policy measures included in CSO23

Important new national policy measures included in CSO23:[10]

- the *green tax reform for industry etc. agreement*, 2022
- the *mileage-based road tax on heavy-duty vehicles agreement*, 2020. Although this agreement has been known since 2020, it has not been possible to include the impacts of the road tax in previous climate and status outlook reports because the basis for modelling had yet to be concretised
- the *climate agreement on green power and heating*, 2022
- the *additional agreement on Energy Island Bornholm*, 2022
- the *follow-up agreement on a climate plan for a green waste sector and circular economy*, 2022.

The North Sea Energy Island has not been included in this year's basic scenario, because establishment of this island depends on measures that have yet to be decided and therefore cannot be included as frozen policy. A possible deployment of 4GW offshore wind power under the *climate agreement on green power and heating* has also not been included in the CSO23 basic scenario.[11]

New EU measures included in CSO23

New EU policy measures included in CSO23 include:[12]

- The provisional agreement on a revision of the EU ETS (EU ETS 1) has been recognised in CSO23 to the extent that the effect of the agreement is reflected in the allowance price. With regard to aviation and the inclusion of shipping, the revised EU ETS 1 has not been included in CSO23.

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[10] See table 2.1 in chapter 2 of the CSO23 memorandum on sector assumptions on principles and policies.

[11] This is because, with the assumptions otherwise underlying the projections, the model runs reveal no room in the electricity market for integrating an additional 4GW offshore wind. Instead, a sensitivity analysis has been performed, which included the North Sea Energy Island and the additional 4GW offshore wind.

[12] See table 2.2 in chapter 2 of the CSO23 memorandum on sector assumptions on principles and policies.

- The provisional agreement on stricter CO_2 emission performance standards for new cars and vans.

The proposed new, separate ETS for buildings and road transport (EU ETS 2) has not been included in CSO23. This is because, at the time of drafting this report, it was not possible to estimate the possible allowance price developments in such a new ETS. Similarly, it has not been possible to estimate the impact of the CO_2 border adjustment mechanism, which is also a part of the EU Fit for 55 package.

Updated expectations about fuel and CO_2 allowance prices

Emissions in CSO23 are also affected by updated expectations about the CO_2 allowance price and fossil fuel prices. The allowance price is from the January 2023 forecast by the Ministry of Finance, which is based on the average EU ETS allowance price in December 2022 and therefore can be assumed to reflect to some extent the market's reaction to the December 2022 agreement on a revision of the EU ETS. The CSO23 allowance price starts at around the same level as the CSO22 allowance price, but it follows a steeper increase. Thus, by 2030, the CSO23 allowance price is estimated to be DKK 850 per tonne, and by 2035 it is estimated to be DKK 1,058 per tonne (estimated in 2022 prices). For more, see chapter 2 of the CSO23 memorandum on sector assumptions on prices and growth.

Fuel prices have changed significantly since CSO22. In CSO23 both fossil fuel prices and biomass prices are estimated to be significantly higher than the prices in CSO22 in the short term. Furthermore, the estimated prices of coal and natural gas remain higher than the CSO22 prices throughout the projection period (see also chapter 1 of the CSO23 memorandum on sector assumptions on prices and growth).

Updated expectations about market developments, etc.

In addition to developments in fuel and CO_2 allowance prices, updated expectations about other market developments, etc. also have significance for developments in emissions in CSO23. For example, agriculture market demand has been updated. Agriculture market demand is significant for the amount of livestock and crops produced by the agriculture sector. Compared with CSO22, CSO23 expects fewer head of cattle throughout the projection period, as well as fewer pigs in the period up to 2030, while the number of pigs is expected to exceed the CSO22 level towards the end of the projection period.

Updated data basis and methodological approach, etc.

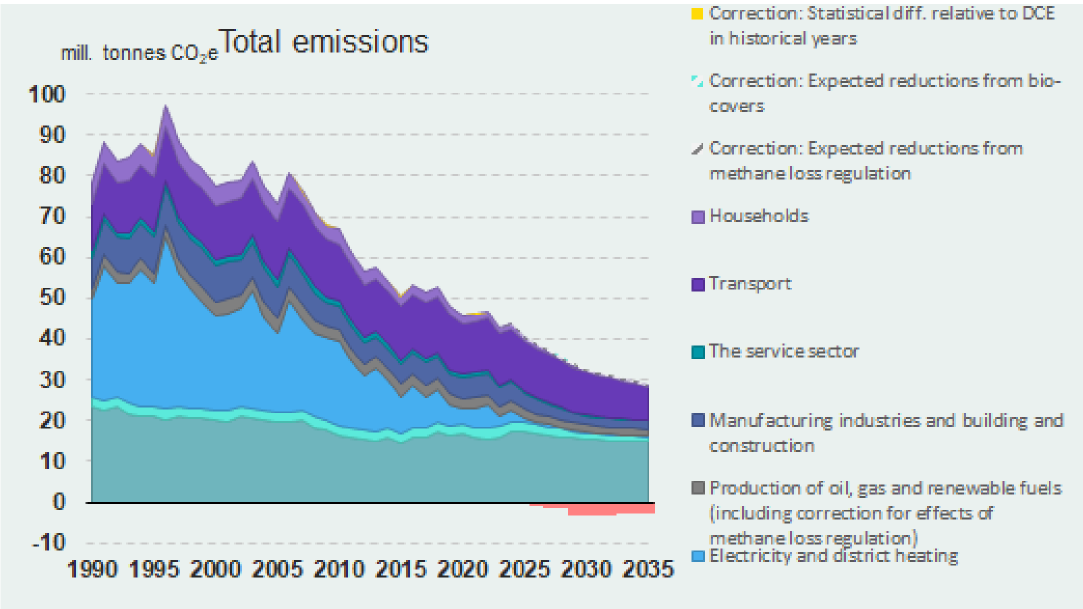
The data basis for projections is updated and improved continuously, and this also has significance for some projections. Important updates to the data basis for CSO23 include updated analyses of energy consumption and energy savings in agriculture and industry (see Viegand Maagøe for the Danish Energy Agency, 2022).

Process emissions from agriculture have been recalculated using the IPCC 2019 emission factors instead of the IPCC 2006 factors used in CSO22, and the calculation of these emissions has moreover been corrected with regard to storage of slurry. Both of these changes have significance for the historical as well as the projected emissions. Similarly, with regard to 'Other waste', the Danish Centre for Environment and Energy (DCE) has made changes to its estimate of emissions from landfilled waste, and this has significance for the historical as well as the projected emissions.

2.3 Trends in emissions across sectors

Developments in total net emissions are a result of developments in the various underlying sectors. Figure 2.3 illustrates developments in the individual sectors from 1990 up to 2021 and the expected developments in the projection period from 2022 to 2035 for these sectors, as well as for carbon capture and storage (CCS). Table 2.2 shows sector emissions data in selected years: 2021, 2025 and 2030.

Figure 2.3: Total emissions by sector, and CCS



Note: In CSO23, CCS is dealt with as negative emissions not broken down by sector (see section 2.4). Emissions in the figure are based on the CRF estimates; i.e. emissions have not been corrected for the expected effect of methane loss regulation and bio-covers, but the expected reductions from these measures are identified in the figure.

Table 2.2: Total emissions by sector, and CCS in selected years

	1990	2021	2025	2030	2035
Households	5.1	1.7	0.9	0.4	0.3
Transport	11.7	12.6	12.2	10.5	8.2
Service sector	1.5	0.8	0.4	0.2	0.1
Manufacturing industries and building and construction	8	5.3	4	2.1	2
Production of oil, gas and renewable fuels (including correction for effects of methane loss regulation)	2	2.5	2.1	1.9	1.8
Electricity and district heating	24.4	5	1.2	0.1	0.1
Waste (incl. waste incineration and correction for the effect of bio-covers)	2.5	2.3	2.2	1.7	1.2
Agriculture, forests, horticulture and fisheries	23.2	15.9	17.4	15.3	14.9
CCS	0	0	-0.5	-3.2	-2.7

Note: See the note to figure 2.3 and appendix 5 on partial corrections for the effects of methane loss regulation and bio-covers.

Trends in emissions across sectors over time

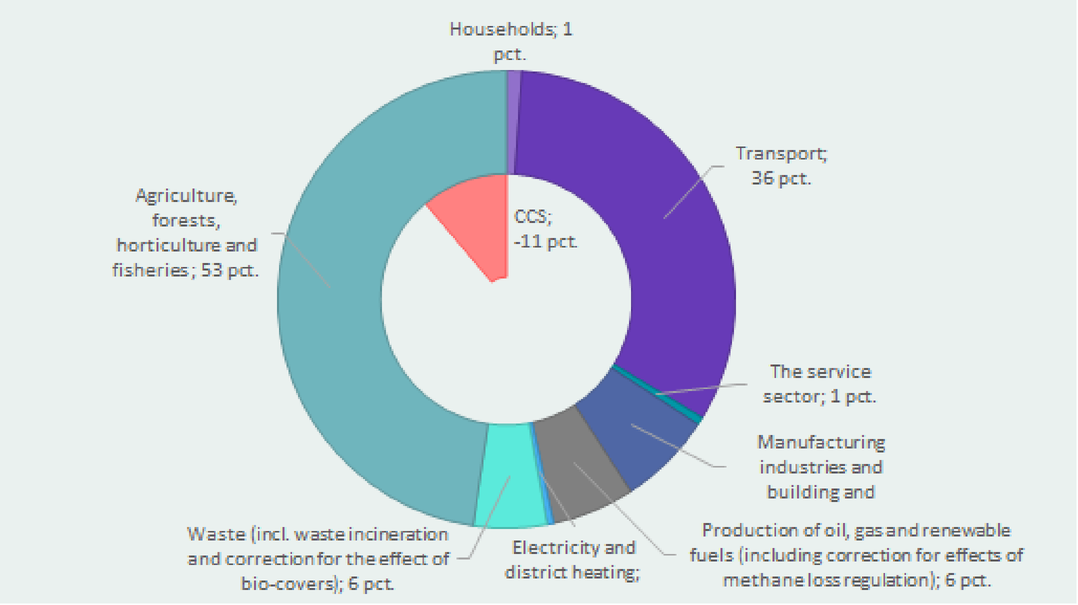
Up to 2010, the electricity and district heating sector (excluding waste incineration) typically accounted for between 30% and 40% of total Danish emissions, but the share has since dropped significantly, see figure 2.3, and in 2021, the sector accounted for only 11% of total emissions. This share is expected to have fallen to 3% in 2025, and in 2030 electricity and district heating (excluding waste incineration) is expected to account for less than 1% of total net emissions.[13] Furthermore, the electricity and district heating sector has seen significant fluctuations in emissions historically. These fluctuations have been due primarily to weather conditions, such as cold winters or fluctuating precipitation in the Nordic countries (affecting Nordic hydropower production). Fluctuations are expected to decrease in future as total emissions from the electricity and district heating sector are reduced as a consequence of phasing-out fossil power plants and the transition to electricity production based primarily on wind, solar and biomass.

As emissions from electricity and district heating production fall, the other sectors' share of total emissions will increase given that they are not falling to the same extent. Historically, emissions from agriculture, forests, horticulture and fisheries (which include emissions from agricultural processes, agricultural land and forest land, as well as energy consumption by the sector) have therefore gone from contributing around 25% of total emissions to contributing 34% of total emissions in 2021. In 2025, this sector is expected to account for 44% of net emissions, while in 2030 the sector's share of total emissions is expected to have increased further to 53%. Similarly, the transport sector's share of total net emissions grew from 15% in 1990 to 27% in 2021, and in 2025 and 2030, 31% and 36%, respectively, of net emissions are expected to stem from the transport sector.

[13] Waste incineration also contributes to electricity and district heating production. If emissions from waste incineration are included with emissions from the electricity and district heating sector, these sectors accounted for 14% of net emissions in 2021 and are expected to make up 7% in 2025 and 4% in 2030. Furthermore, private autoproducers in other sectors also contribute to electricity and district heating production, although emissions from this production are relatively limited (see also sector memorandum 8A).

How total emissions in 2030 distribute across sectors is illustrated in figure 2.3.[14] As can be seen from the figure, emissions in 2030 will be concentrated on relatively few sectors. It is expected that almost 90% of the total net emissions of 29.5 million tonnes CO_2e after recognition of partial corrections will stem from either agriculture, forests, horticulture and fisheries or the transport sector. CCS also plays a significant role for emissions, as CCS is expected to offset 11% of total net emissions in 2030. If we look instead at gross emissions (i.e. emissions before recognition of CCS), then the contribution from agriculture, forests, horticulture and fisheries and the transport sector will be 80% in 2030.

Figure 2.4: The sector's share of total net emissions in 2030



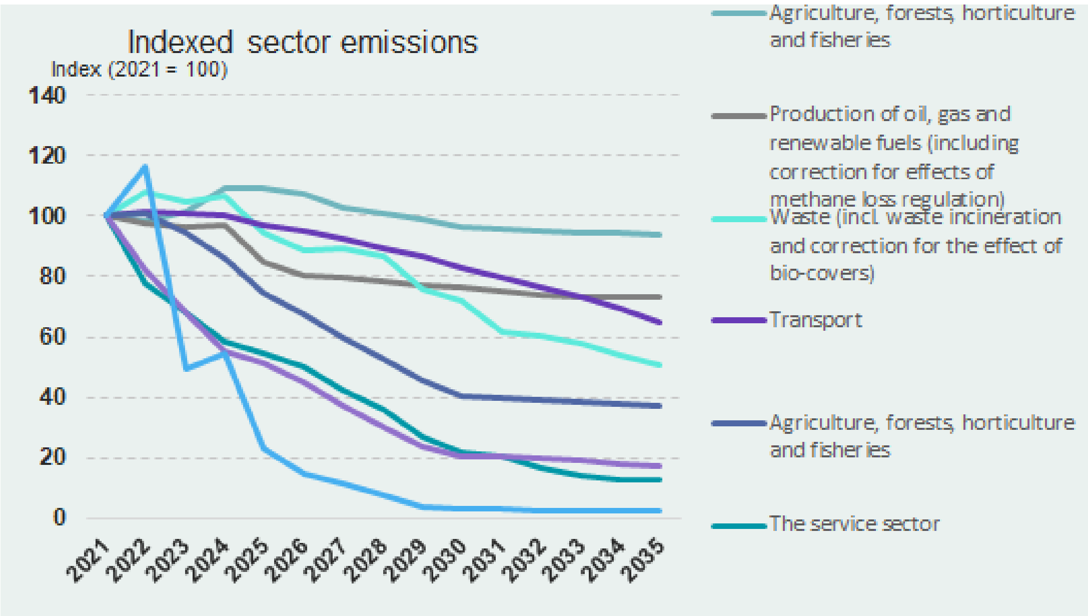
Note: In CSO23, CCS is dealt with as negative emissions not broken down by sector (see section 2.4).

2.4 Projection of individual sector emissions 2019-2035

There is not only a difference between how large a share of total emissions can be attributed to the individual sectors, but there are also significant differences in how emissions from the individual sectors are projected to develop during the projection period. This can be seen in figure 2.5, which shows the trends in sector emissions compared to the base year 2021, the most recent statistical year. Below are brief descriptions of the emissions trends in individual sectors.

[14] Note that the breakdown in CSO23 has been changed slightly compared with CSO22. This is because, in CSO23, methane leaks from biogas plants have been included under the 'production of oil, gas and renewable fuels' sector. In CSO22, these emissions were included under the waste sector.

Figure 2.5: Trends in sector emissions 2021-2035 (2021 = index 100)



Note: CCS is not illustrated in this figure, as the technology was not established in 2021.

Agriculture

Emissions from agriculture, forests, horticulture and fisheries were 15.9 million tonnes CO_2e in 2021. Emissions are expected to increase to 17.4 million tonnes CO_2e in 2025, after which they will decrease to 15.3 million tonnes CO_2e and 14.9 million tonnes CO_2e in 2030 and 2035, respectively, corresponding to a fall of 3% in 2030 and 6% in 2035 compared to 2021. Developments in total sector emissions distribute differently across the individual subsectors.

Thus, emissions from agricultural processes (primarily from livestock digestion and fertiliser use) will fall from 12.1 million tonnes CO_2e in 2019 to 10.4 million tonnes CO_2e in 2030, for example as a result of falling livestock numbers in the projection period (most pronounced for cattle) as well as measures under the *2021 agreement on a green transition of the agricultural sector* such as reduction requirements for livestock digestion, more frequent slurry flushing, extensification, etc. LULUCF emissions from agricultural land will fall from 5.1 million tonnes CO_2e in 2021 to 4.7 million tonnes CO_2e in 2025 and 3.7 million tonnes CO_2e in 2030. This fall in emissions will mainly be due to set-aside and rewetting carbon-rich soils. Forests will go from contributing net removals of 2.9 million tonnes CO_2e in 2021 to net emissions of 0.3 million tonnes CO_2e in 2025. From 2030 onwards forests are again expected to contribute slightly with removals.

The 2021 *agreement on a green transition of the agricultural sector* established a binding reduction target for greenhouse gas emissions by the agriculture and forestry sector of 55-65% by 2030 compared to 1990. With regard to this target, CSO23 projects a reduction in emissions of 31% by 2030. This leaves an estimated emissions gap of around 24-34% from the 2030 target, corresponding to 5.1-7.2 million tonnes CO_2e.

CSO23 estimates emissions from agriculture, forests, horticulture and fisheries to be higher throughout the projection period than CSO22. This is primarily due to recalculation of emissions from agricultural processes. The difference to CSO22 is greatest in the period up to 2026, after which fewer head of cattle reduces the difference.

Transport

Emissions from the transport sector were at 12.6 million tonnes CO_2e in 2021. Transport emissions are expected to fall to 12.2 million tonnes CO_2e in 2025 and 10.5 million tonnes CO_2e in 2030, and this fall is expected to continue up to 2035, when transport emissions are expected to have been reduced to 8.2 million tonnes CO_2e, corresponding to a decrease of almost 35% compared to 2021. The fall in transport emissions is projected despite increasing traffic and is due to a combination of transitioning from conventional to electric vehicles, renewable fuels blending and improved energy efficiency for conventional vehicles.

The passenger car fleet is lower in CSO23 than in CSO22, but as traffic is more or less the same, emissions from passenger cars are only slightly affected. With regard to new sales, tightening of the EU Regulation on CO_2 emissions reduction requirements in practice means a ban on sales of new cars and vans with internal combustion engines (including plug-in hybrids) in the EU from 2035. For heavy transport, the introduction from 2025 of a mileage-based road tax on lorries in Denmark (differentiated based on CO_2 emissions) is expected to curb the increase in traffic by lorries and increase the incentive to invest in electric lorries. Emissions from lorries are therefore expected to drop from 2025 and onwards.

Outside road transport, the projection period will see increased railway electrification, and this will lead to emissions from railways falling from 0.2 million tonnes CO_2e in 2021 to zero from 2031 and onwards.

CSO23 has slightly lower transport emissions than CSO22 throughout the projection period. This is not least due to lower emissions from lorries.

Production of oil, gas and renewable fuels

Emissions from production of oil, gas and renewable fuels include emissions associated with extraction in the North Sea, emissions from refineries and, as something new, methane leaks from biogas plants (CSO22 reported these under the waste sector).

Emissions from production of oil, gas and renewable fuels came to 2.5 million tonnes CO_2e in 2021. During the projection period, emissions from the sector (including correction for the effect of the methane loss regulation scheme, see below) are expected to peak at 2.4 million tonnes CO_2e in 2024, after which they will fall again to 2.1 million tonnes CO_2e by 2025, 1.9 million tonnes CO_2e by 2030 and 1.8 million tonnes CO_2e by 2035. The peak emissions in 2024 are due to commencement of operation of the Tyra field in the North Sea. Emissions from refineries have been assumed to fall following introduction of a CO_2 tax with the *green tax reform for industry etc. agreement*.

Methane emissions resulting from leaks from biogas plants are more or less proportional to developments in biogas production. The *climate agreement on green power and heating* introduced a regulation scheme for methane losses from biogas plants. The expected lower emissions due to this scheme have not been recognised in the CSO23 CRF estimate but have been partially deducted in the emissions gap estimates, etc. It is assumed the scheme will have an effect on emissions from 2024. After correction for the estimated effect of methane loss regulation, methane emissions resulting from leaks from biogas plants are therefore projected to drop significantly from 2023 to 2024. In calculation of the correction for the effect of methane loss regulation in CSO23, it has been assumed that all biogas plants will reduce their methane losses to 1% from 2024. Note that the scheme only requires upgrading plants to reduce methane losses to 1% from 2024, whereas biogas plants are required to reduce losses 'as much as possible'. This means that the expected effect of methane loss regulation is uncertain because biogas plants will have to identify and plan remediation of any sources of methane loss, for example. In 2025, a measurement project will be performed to document the actual effect of the methane loss regulation scheme.

In CSO23, emissions from production of oil, gas and renewable fuels are significantly lower compared with CSO22. This is a result of a downward adjustment of the production forecast, as well as of the effect of the green tax reform on the energy consumption and emissions of refineries. Recognition of the expected effect of methane loss regulation lowers CSO23 emissions additionally compared with CSO22.

Manufacturing industries and building and construction

Emissions from manufacturing industries and building and construction are estimated to fall from 5.3 million tonnes CO_2e in 2021 to 4.0 million tonnes CO_2e in 2025, 2.1 million tonnes CO_2e in 2030 and 2.0 million tonnes CO_2e in 2035. Among things, the fall is due to the *green tax reform*, which is set to impose a general CO_2 tax on ETS and non-ETS companies. The tax will be phased in from 2025 and up to 2030. The reform will provide a greater incentive to convert away from fossil fuels and to carry out energy efficiency improvements. It is expected it will give rise to large structural changes in manufacturing industries. In particular, a large fall in Danish domestic production of cement is expected. Furthermore, an increasing share of renewables in mains gas will also contribute to reductions in the sector's emissions.

In CSO23, emissions from manufacturing industries and building and construction are significantly lower from 2025 and onwards than in CSO22. In particular, this reflects the likely structural effect the CO_2 tax will have on cement production and on conversions to renewable alternatives such as electric heat pumps and biomass.

Households and the service sector

Emissions from households are estimated to fall from 1.7 million tonnes CO_2e in 2021 to 0.9 million tonnes CO_2e in 2025, 0.4 million tonnes CO_2e in 2030 and 0.3 million tonnes CO_2e in 2035. By far the majority of emissions from households stem from individual heating, and the drop in emissions is due to a combination of conversions from oil- and gas-fired heating to collective district heating or individual heat pumps, the drastically increasing renewables share in mains gas for those who still have gas-fired boilers, as well as energy efficiency improvements making it possible to meet the same demand with less energy. CSO23 has lower household emissions than CSO22 throughout the projection period. Note that ongoing heating planning by local governments is not reflected in CSO23.

Emissions from the service sector are estimated to fall from 0.8 million tonnes CO_2e in 2021 to 0.4 million tonnes CO_2e in 2025, 0.2 million tonnes CO_2e in 2030 and 0.1 million tonnes CO_2e in 2035. At the beginning of the projection period, the majority of service sector emissions stem from individual heating, but as energy-related emissions drop, emissions of F gases from refrigerants in refrigeration and freezing plants and heat pumps will constitute a still greater share of the sector's emissions. The fall in energy-related emissions is partly attributable to the phasing-out of mains gas through conversion to heat pumps for space heating, as well as the increasing renewables share in mains gas, which will reduce emissions from remaining mains gas consumption. In CSO23, emissions from the service sector are lower from 2023 and onwards than in CSO22.

The electricity and district heating sector

Emissions from the electricity and district heating sector are estimated to fall from 5.0 and 5.8 million tonnes CO_2e in 2021 and 2022, respectively, to 1.2 million tonnes CO_2e in 2025. In 2030 and 2035, the sector is expected to emit only 0.1 million tonnes CO_2e. The background for the significant decrease in emissions is primarily in phase-out of the remaining coal-fired CHP plants, continued wind and solar PV deployments, significant heat pump deployments for district heating production, as well as a reduction in CHP production based on mains gas.

Energy Island Bornholm has been included in the basic scenario in CSO23 (see the *additional agreement on Energy Island Bornholm* from 2022). The North Sea Energy Island and the 4GW offshore wind power under the *climate agreement on green power and heating* have not been included in the CSO23 basic scenario. However, the system and climate implications of the higher quantities of offshore wind for the Danish electricity and district heating sector have been described through a sensitivity analysis.

In CSO23, emissions from the electricity and district heating sector are significantly higher in 2022 and 2024 than in CSO22, but emissions are slightly lower in the period up to 2032, particularly in 2026 and 2027. This is partly because the fuel mix in thermal electricity production is very sensitive to changes in relative fuel prices and in the electricity price.

The waste sector (including waste incineration)

Emissions from the waste sector came to 2.4 million tonnes CO_2e in 2021 and are estimated to be at 2.5 million tonnes CO_2e up to 2024, after which emissions are estimated to fall to 2.2 million tonnes CO_2e in 2025, 1.7 million tonnes CO_2e in 2030 and 1.2 million tonnes CO_2e in 2035. The waste sector includes emissions from waste incineration, landfilling, composting and wastewater (while emissions linked to methane leaks from biogas plants are now, as opposed to previous reports, included under the 'production of oil, gas and renewable fuels sector').

Emissions from waste incineration were 1.6 million tonnes CO_2e in 2021 and will increase to 1.8 million tonnes CO_2e in 2022. After this, emissions are expected to fall to 1.5 million tonnes CO_2e in 2025, 1.0 million tonnes CO_2e in 2030 and 0.5 million tonnes CO_2e in 2035. The CSO23 trajectory follows the government's impact assessment of deregulation of the waste incineration sector (see the Waste Incineration Sector Restructuring, etc. Bill). The CSO23 trajectory entails less available incineration capacity in the period 2025-2035 than CSO22 (after adjustment for recovery rate). Furthermore, stronger oversight of recyclable industrial waste (see the *follow-up agreement on a climate plan for a green waste sector and circular economy*) is estimated to reduce Danish waste volumes compared to CSO22, and to increase the fossil share (by weight) in remaining Danish waste volumes. CSO23 estimates emissions from waste incineration to be lower in 2025-2026 and higher in 2027-2033 than CSO22.

Emissions from landfilling are lower than in CSO23 than in CSO22. This is because the Danish Centre for Environment and Energy (DCE) has downward-adjusted its estimates of the volumes of organic waste in landfills. Furthermore, CSO23 includes the expected effect of bio-covers, in that this effect has been partially deducted in emissions gap estimates, etc.

CCS (carbon capture and storage)

CCS is considered a source of reduced emissions from fossil point sources or a source of negative emissions if the technology is used to capture biogenic emissions or CO_2 from the atmosphere. As in previous years' reports, in this year's report CCS is included as a source of emissions reductions, not broken down by sector. Thus, just as previous reports, CSO23 recognises CCS as a separate source of negative emissions, not broken down by sector. As CCS is not dealt with broken down by sectors, CCS has not been included as an integral part of system calculations for CSO23, and derived effects (e.g. with regard to energy consumption, etc.) will therefore not be reflected in the projected figures.

CCS is expected to be realised as a consequence of the *market-based subsidy pool for CCUS* (part of the 2020 *climate agreement for energy and industry, etc.*), the technology-neutral tendering procedure for negative emissions (the so-called NECSS pool under the 2022 Finance Act) as well as the new CCS pool under the *green tax reform*. The expected annual CO_2 emissions reduction effect from CCS is illustrated in table 2.3 below.

Table 2.3: Recognised annual CO_2 emissions reduction effect from CCS

CO_2 (million tonnes)	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
CCUS pool	0	0	0	0.0	0.4	0.4	0.4	0.9	0.9	0.9	0.9	0.9	0.9	0.9
NECSS pool	0	0	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0	0	0
Green tax reform pool	0	0	0	0	0.2	0.5	0.5	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Total reduction effect	**0**	**0**	**0**	**0.5**	**1.1**	**1.4**	**1.4**	**3.2**	**3.2**	**3.2**	**3.2**	**2.7**	**2.7**	**2.7**

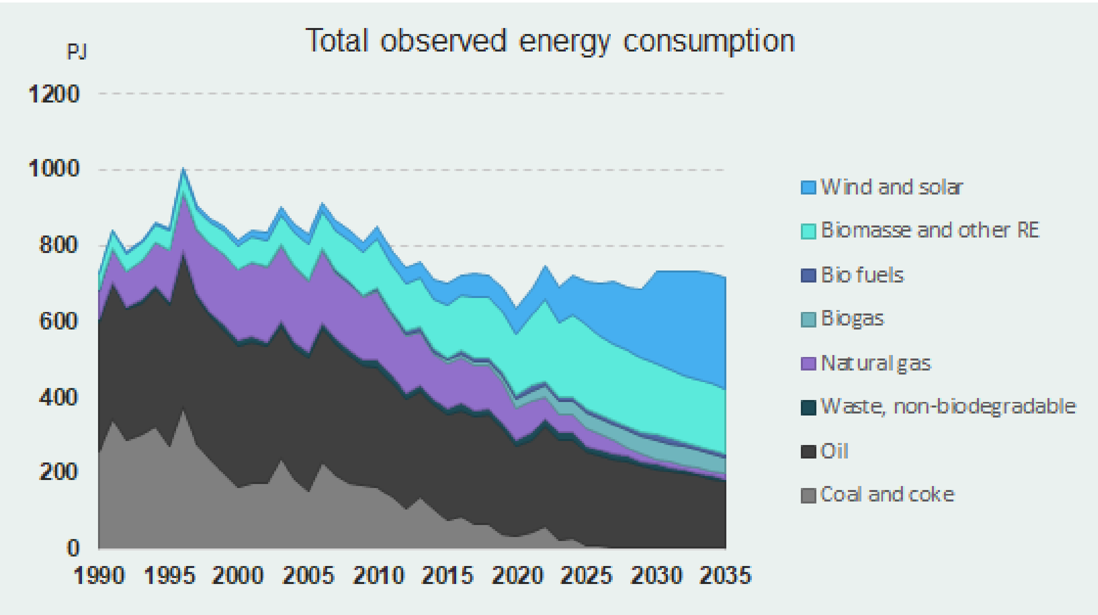
Source: CSO23 memorandum on assumptions about CCS (2023)

In the first award round of CCUS, funds were awarded to Ørsted on 15 May 2023, and the expected resulting storage of 0.034 million tonnes of CO_2 by 2025 and 0.43 million tonnes CO_2 per year after that, have been included in the estimate of CSO23 total net emissions. However, CSO23 still recognises the effect of the CCUS pool as part of the total reduction effect from CCS (i.e. not by sector).

2.5 Total energy consumption and renewable energy shares

Developments in energy-related emissions depend on total energy consumption as well as on the share of renewable energy in energy consumption. Figure 2.6 shows the energy mix and developments observed in Danish energy consumption from 1990 to today, and onwards up to 2035.

Figure 2.6: Total observed energy consumption by type of energy (PJ)



Note: Total observed energy consumption also includes oil-gas extraction in the North Sea.

Renewable energy covers a large number of renewable energy sources, from wind and solar over solid biomass to bioliquids and biogas, etc. Some renewable energy sources can be included directly in final energy consumption by the sector, for example wood pellets for space heating and process heat, while other renewable energy sources are used in the production of energy products such as electricity, district heating, mains gas and transport fuels. Following the UN IPCC methodology, emissions from biomass burning are counted as *zero emissions* in the sector consuming the biomass. This is because emissions from harvesting the biomass have already been accounted for. Biogenic energy-related CO_2 emissions, on the other hand, are reported as a so-called memo item (see chapter three of the CSO23 memorandum on sector assumptions about principles and policies). The biogenic CO_2 emissions from total Danish consumption of biomass for energy-related purposes are shown in Appendix 6.[15]

Renewables shares in mains gas, transport fuels and electricity supply

While emissions associated with electricity and district heating production are attributed to the electricity and district heating sector (and, as far as emissions from waste incineration go, to the waste sector), emissions associated with consumption of mains gas and transport fuels are attributed to the relevant consuming sector. Emissions from these sectors are therefore determined by the renewables share in mains gas and transport fuels.

Table 2.4: Renewables shares in electricity consumption, mains gas and transport fuels, as well as total renewables share

	2021	2025	2030	2035
Renewables share in electricity consumption (RES-E)	73%	85%	117%	118%
Renewables share in mains gas (RES-G)	22%	50%	108%	127%
Renewables share in transport fuels	5%	6%	9%	9%
Total renewables share (RES) (before sales)	42%	53%	71%	79%

Note: Total RES is calculated before statistical transfers between Denmark and other EU Member States. For more about Denmark's statistical transfer agreements with other Member States, see CSO23 sector memorandum 11B. For RES and RES-E, biogas and biomass used at large electricity and heating plants have been recognised in all of 2021 despite EU methodologies implying that only biogas and biomass used in the second half of the year should be included in the calculation of the renewables share Due to the transition from Renewable Energy Directive I (RED I) to Renewable Energy Directive II (RED II), the EU only recognises biogas and biomass as part of the renewables share in the second half-year of 2021.

As can be seen from table 2.4, in CSO23, the renewables share in mains gas follows a steep increase in the projection period, from 22% in 2021 to 50% in 2025, and from 2030 the production of upgraded biogas exceeds the demand for mains gas, and after 2030 the estimate shows no further (fossil) emissions linked to the consumption of mains gas. For comparison, in CSO22 the renewables share in mains gas was

[15]The corresponding biogenic energy-related CO_2 emissions from the individual sectors are in appendices to the relevant underlying sector memoranda.

estimated to be 38% in 2025, 75% in 2030, and 92% in 2035. The significant increase is largely due to a significant drop in total mains gas consumption, which are projected to be 20-30% lower from 2024 than projected in CSO22. Note that projections of mains gas consumption are relatively sensitive to assumed developments in prices and activity levels in industry. Note also that the renewables share in mains gas will change for all gas consumers if there is a change in mains gas consumption.[16]

The renewables shares in transport fuels increase from 5% in 2021 to 6% in 2025 and 9% in 2030.[17] The renewables share in transport fuels primarily depends on the national CO_2 displacement requirement for transport fuels and so is only slightly dependent on the total consumption of transport fuels (see also CSO23 sector memorandum 4B).

The renewables share in electricity supply (RES-E) is also projected to increase, from 63% in 2021 to 117% in 2030. RES-E is a measure of surplus/shortage of renewables-based electricity production in the Danish electricity system compared to Danish electricity demand, and therefore RES-E can exceed 100%. Note that meeting the target in the PtX strategy and establishing the North Sea Energy Island, for example, which have not been included in the CSO23 basic scenario, will significantly increase both the demand and the supply of electricity compared to the levels in CSO23.

CSO23 estimates the renewables share in total energy consumption (which is calculated as observed final renewable energy consumption as a proportion of gross final energy consumption) to increase from 42% in 2021 to 53% in 2025, 71% in 2030 and 79% in 2035.

2.6 Status on Denmark's performance on its EU obligations

In addition to the national emissions reduction targets set out in the Danish Climate Act, Denmark is subject to emissions reduction targets in the context of the EU in the form of effort sharing and LULUCF obligations.[18] These targets have been tightened since CSO22 in connection with the EU's Fit for 55 package of legislation.

[16] This is because the renewables share in mains gas consists of upgraded biogas, and the amount of biogas produced depends on the demand, in that it is assumed largely to be determined by subsidy schemes (see chapter 3 of the CSO23 memorandum on sector assumptions on production of oil, gas and renewables as well as CSO23 sector memoranda 7B and 7C). A reduction in the demand for mains gas would therefore result in a corresponding reduction in the consumption of fossil natural gas. A reduction in the consumption of mains gas in a given sector will therefore also lower emissions from mains gas consumption in other sectors because the renewables share in mains gas increases at the same time.

[17] Note that the calculated renewables share in transport fuels differs from the RES-T used in the EU estimates. Amongst other things, RES-T includes the different types of biofuels with different weightings depending on their origin and the type of biomass used, just as it includes electricity consumption by electric road transport and electric rail transport with different weightings.

[18] See chapter 11 as well as CSO23 sector memorandum 11A for more explanation of these EU obligations and Denmark's possibilities for closing emissions gaps.

Effort sharing obligation

Denmark's EU effort sharing obligation includes Danish emissions not covered by ETS 1 and LULUCF. The effort-sharing target includes emissions from agricultural processes, transport, non-energy-intensive industries, waste/wastewater, small district heating and CHP plants, and households. The emissions gap relative to the effort sharing target is calculated as the accumulated deviation from a specific reduction trajectory for the period 2021 to 2030. The reduction trajectory depends, in particular, on the 2030 target stipulated for Denmark. This target has been tightened, from a 39% emissions reduction target to a 50% emissions reduction target, measured against 2005 emissions. With the projected developments in emissions in CSO23, Denmark's accumulated effort sharing emissions gap for the period 2021 to 2030 is around 16 million tonnes CO_2e, after recognition of the expected effects of methane loss regulation and bio-covers.

LULUCF obligation

Denmark's obligation with regard to LULUCF sector emissions and removals includes the following categories: agricultural land, forest land and harvested wood products (HWP), and, from 2026, settlements and wetlands. Denmark's LULUCF reduction target is divided into the following sub periods: 2021-2025, 2026-2029 and 2030. Reduction targets for the years 2026-2030 have been tightened considerably, as have the LULUCF accounting rules in that the possibility of transferring LULUCF credits from 2021-2025 to 2026-2030 has been removed. With the projected developments in emissions in CSO23, Denmark's LULUCF reduction target for the period 2021 to 2025 is expected to be exceeded by around 13 million tonnes CO_2e, while for the period 2026-2029 and for 2030, there will be emissions gaps of around 9 million tonnes CO_2e and 2 million tonnes CO_2e, respectively.

2.7 Uncertainty

As mentioned in chapter 1, it is important to remember that the projections in CSO23 are subject to considerable uncertainty. This applies to general uncertainty linked to projecting greenhouse gas emissions, as well as the specific uncertainty linked to developments in energy prices and energy markets, as well as any long-term effects of the Covid-19 pandemic.

General uncertainty

The general uncertainty in projections is linked to difficulties projecting the developments in activity in society in general as well as in businesses with considerable greenhouse gas emissions (e.g. cement production and agricultural production).

Another general source of uncertainty in the projection concerns uncertainty about investment behaviour, including, in particular, the phase-in rate for new technologies (e.g. electric vehicles in transport, emerging shifts away from fossil fuels in manufacturing industries and transitioning from natural gas boilers to other heating technologies in households). Furthermore, there is uncertainty about the size of the effect of the CCS pools, the significance of which increases with time for net emissions throughout the projection period (see also the CSO23 memorandum on assumptions about CCS).

Finally, there is general uncertainty associated with the projection's assumptions, including assumptions about economic growth, price developments for resource inputs and technological advances.

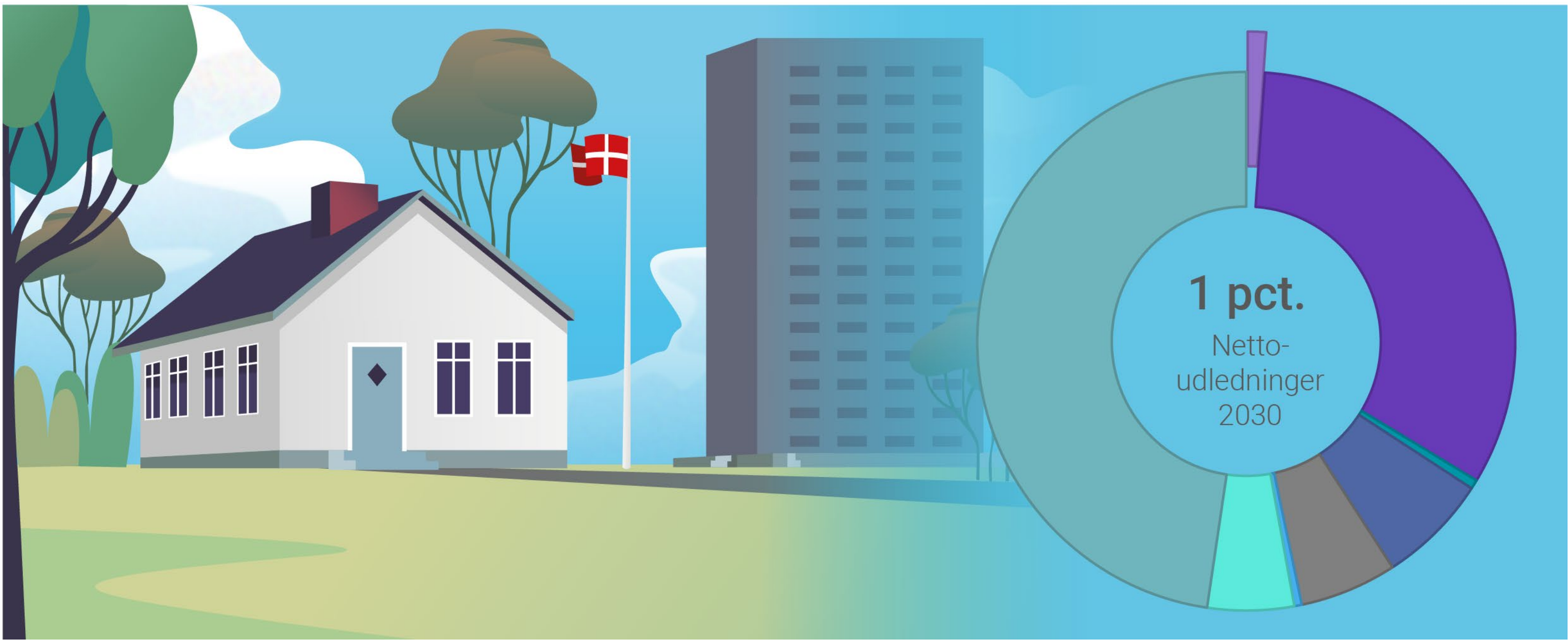
The Covid-19 pandemic and the energy crisis

There continues to be uncertainty about the potential, permanent consequences of the Covid-19 pandemic, including whether any unforeseen structural or behavioural changes will occur in the long term. Note, in this connection, that 2021 is the most recent statistical year in CSO23 but that, in many cases, the underlying projection is based on 2019, which is assessed to be a more fitting and true projection basis.

Developments in energy markets and the energy crisis exacerbate uncertainty about the projections. There is considerable uncertainty about the future energy prices included in the projections, and uncertainty in the energy markets can also affect the preferences of households and industry when choosing heating technology. Any shifts in these preferences will not manifest themselves until after some years. Because the energy crisis is a global phenomenon, international supply possibilities and problems can also have an effect, at any given time, on opportunities for transitioning the energy sector.

Sensitivity analyses

The following sector chapters include examples of important uncertainties and, in some cases, sensitivity analyses for the relevant sectors. The underlying sector memoranda provide further in-depth descriptions of these.



3 Households

The household sector comprises all citizens residing in Denmark. About 5.9 million people live in around 2.7 million homes.[19] All homes need heating, and some have this need met through collective district heating, while others rely on individual heating technologies such as heat pump and gas-fired boilers.[20] Furthermore, all households use a variety of electrical appliances for lighting, washing and cleaning, cooking and food storage, as well as for entertainment.

In CSO23, greenhouse gas emissions by the household sector have been limited to emissions linked to individual heating and gas-fired patio heaters, petrol-powered lawnmowers, etc., as well as F-gas emissions. Household sector emissions from these sources amounted to 1.7 million tonnes CO_2e in 2021, corresponding to around 4% of total Danish emissions.

According to the projection, emissions by the sector will be 0.9, 0.4 and 0.3 million tonnes CO_2e, respectively, in 2025, 2030 and 2035, corresponding to 3%, 1% and 1%,

[19] Source: StatBank Denmark, Statistics Denmark. The following tables: FOLK1A Population at the first day of the quarter by region, sex, age and marital status; and BOL101: Dwellings by region, type of resident, use and time. Number of dwellings does not include vacant dwellings.

[20] In this memorandum, individual heating technologies cover technologies used to generate space heating and domestic hot water in individual buildings. Gas-fired boilers therefore also fall under individual heating technologies, even though the mains gas is distributed to homes through collective pipes. In addition to heat pumps and gas-fired boilers, the following technologies/heating systems categorise as individual heating: biomass installations, oil-fired boilers and solar heating.

respectively, of total Danish emissions. The expected development in sector emissions is due in particular to household heating becoming less CO_2 intensive

The primary reasons for fewer emissions include:

- conversion away from oil- and gas-fired heating, in particular, to collective district heating and individual heat pumps[21]
- increasing renewables share (biomethane) in mains gas, which reduces emissions from households with gas-fired boilers
- energy efficiency improvements, which means that the same demand can be met by less consumption.[22]

3.1 Household sector emissions

Household sector emissions stem from a subset of energy consumption by the sector, i.e. the share of energy consumption that includes:

- individual heating, in particular oil- and gas-fired heating[23]
- gas-fired patio heaters, petrol-powered lawnmowers and similar (categorised as 'Other').

Furthermore, there are emissions linked to individual heat pumps, as these use refrigerants in the form of F gases. Emissions occur during filling, during operation and in connection with disposal.

Emissions linked to other parts of household energy consumption are 'allocated' to other sectors. More specifically, this applies to emissions linked to household use of transport, which are included under the transport sector (see chapter 4), while emissions from waste incineration are included under the waste sector (see chapter 9). Furthermore, emissions associated with electricity and district heating production are included under the electricity and district heating sector (see chapter 8), regardless of whether these emissions stem from the use of electric vehicles, heat pumps or lighting.

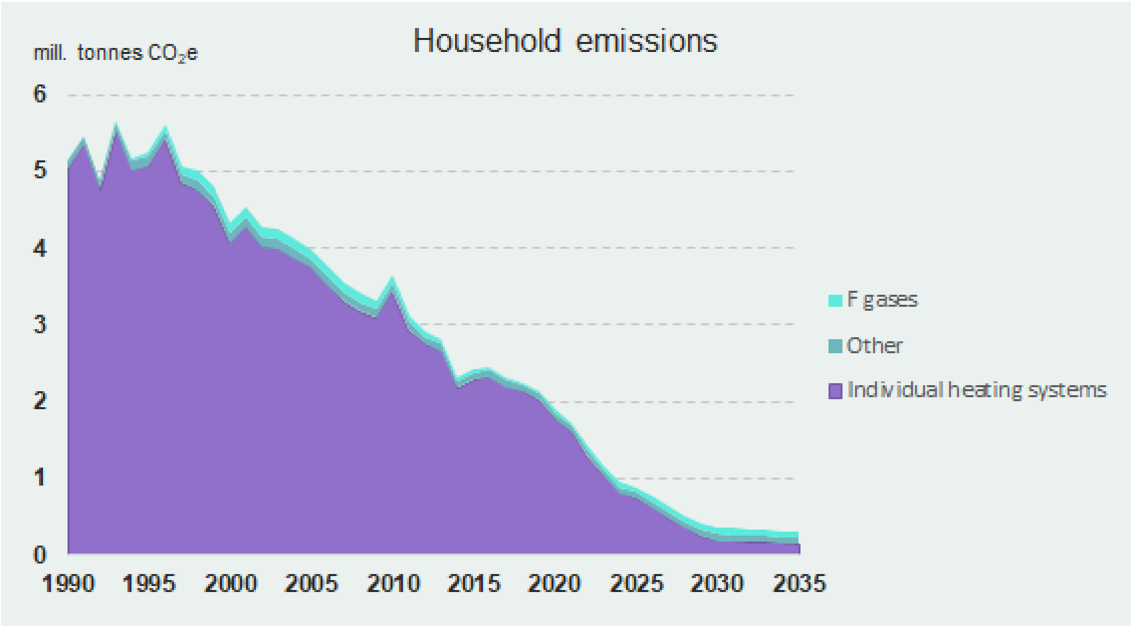
Figure 3.1 shows total household emissions for the period 1990-2035, based on the assumptions referred to above. As can be seen from the figure, CSO23 shows emissions from the sector falling by 80% between 2021 and 2030. The fall in emissions is projected to continue and will have fallen to 0.3 million tonnes CO_2e in 2035.

[21] This reduces household sector emissions, because emissions from district heating fall under the electricity and district heating sector in chapter 8 and are therefore no longer included in this chapter.
[22] For example, energy efficiency improvements are energy improvements in existing homes such as improved insulation, as well as stricter energy requirements in building standards for new buildings. Similarly, conversion to district heating and heat pumps in itself means that households can meet the demand for energy more efficiently. Finally, there are technological improvements.
[23] Individual heating technologies include oil-fired, gas-fired or biomass-fired installations, as well as individual heat pumps and solar heating. Emissions from individual heating stem primarily from oil- and gas-fired heating (CO_2), biomass installations (nitrous oxide and methane) and heat pumps (F gases).

CSO23 projects emissions to be additionally reduced compared with CSO22 both in 2025 and in 2030. From 2021 to 2030, emissions are reduced by an additional 8 percentage points in CSO23 compared with CSO22.

This additional reduction relative to CSO22 is notably due to a large reduction in emissions from individual heating, including, in particular, from the higher renewables share in mains gas in CSO23. The reduction in emissions from individual heating more than outweighs the increase in household emissions of F gases as well as emissions from the category 'Other'.

Figure 3.1 Emissions from households for 1990-2035 in million tonnes CO_2e



Note: The category 'Other' comprises emissions from gas-fired patio heaters, petrol-powered lawnmowers and similar.

The following sections explain the background for developments in the sector's emissions, with special focus on the target years 2025 and 2030 and the final year 2035.

3.2 Household sector framework conditions, etc.

Emissions from individual heating account for by far the majority of emissions from the household sector (see figure 3.1), and in 2022, a number of political agreements were decided that can affect the supply of heat, for example the *climate agreement on green power and heating*, the *agreement on a targeted heating cheque* and the *agreement on a winter support package*, all of which aim to promote district heating and other sustainable heating options. How the agreements have been included in the calculation of future emissions is explained in the CSO23 memorandum on sector assumptions about energy consumption and process emissions by households and the corporate sector (see chapter 2 on heating in households).

The war in Ukraine and the consequential need to phase out Russian gas have led to high energy prices and enhanced political focus on energy consumption, including by the household sector.

3.3 Activity level, efficiency improvements and technology shifts in the household sector

Although households accounted for only 4% of total emissions in 2021, the sector is still responsible for 27% of total final energy consumption.[24]

There has been an increase in energy efficiency improvements and conversion to less CO_2e-intensive heating technologies in households.

Conversion away from oil- and gas-fired heating to heat pumps and district heating
The projection shows that developments are moving towards more district heating and more heat pumps in place of oil- and gas-fired heating, see figure 3.2.

In 2022, just under half of all residential buildings had district heating as their primary heating technology.[25] This share is projected to increase to 58% by 2030 and to continue increasing until 2035.

With regard to individual heating technologies, an increase is projected for heat pumps, whereas there will be fewer residential buildings using oil-fired boilers and gas-fired boilers, biomass installations, etc. (wood pellets, firewood and straw) or electric radiators.

Heat pumps were the primary heating technology in 11% of residential buildings in 2022, and this percentage is expected to rise to 18% in 2030 and 23% in 2035.

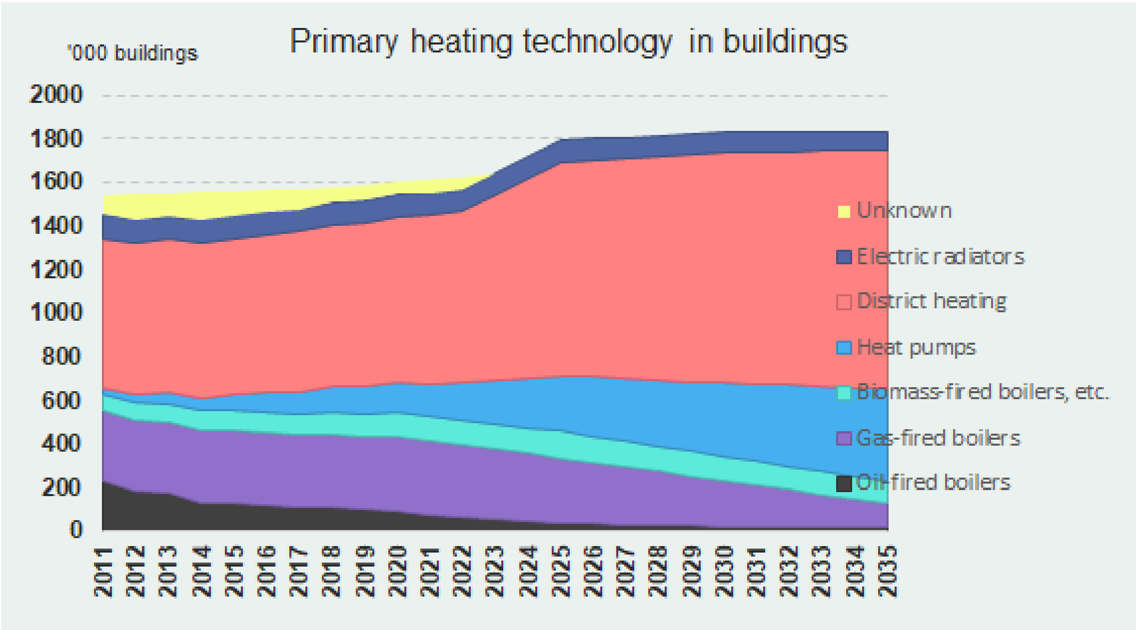
Gas and oil was the primary heating technology in 21% and 4% of residential buildings in 2022, respectively, and these percentages are expected to fall to 6% for gas and 1% for oil in 2035. According to the projection, in 2030, around 210,000 residential buildings will have gas as their primary heating technology and around 23,000 residential buildings will have oil as their primary heating technology. In 2035, around 17,000 residential buildings will use oil for heating and around 110,000 residential buildings will use gas, according to CSO23.

This development may be influenced by any future measures, including measures due to 1) ongoing municipal heat planning and 2) instruments to support the phase out of

[24] This is not only due to a large share of green energy, but it is also due to emissions being 'allocated' to the place of production, whereas energy consumption is 'allocated' to the place of consumption. For example, this means that emissions from electricity and district heating are allocated to the electricity and district heating sector, but electricity and district heating consumption by households is included under household sector consumption.
[25] 2022 is the most recent historical year for this data, which is based on Statistics Denmark, the Danish Building and Dwelling Register and estimates by the Danish Energy Agency.

gas-fired boilers in homes by 2035 under the *2022 climate agreement on green power and heating*.

Figure 3.2: Primary heating technology in buildings for the period 2011-2035 ('000 buildings)



Source: Statistics Denmark, StatBank Denmark and own calculations.
Note: The number of buildings for the individual year reflects the primary heating technology in each building at the end of the preceding year. Statistics Denmark's calculations are based on Danish Building and Dwelling Register figures on number of installations, and these figures are associated with some uncertainty. Other sources of data indicate fewer oil-fired boilers and more heat pumps than data from the Danish Building and Dwelling Register. Therefore, the number of oil-fired boilers has been adjusted downwards compared with the Danish Building and Dwelling Register's data and the number of heat-pump installations has been adjusted upwards compared with Statistics Denmark's data. Because of these adjustments, figure 5 includes a group of buildings for which the heating technology is 'Unknown'.[26]

Energy efficiency improvements lead to less energy consumption for heating

The projection shows that, in 2030, around 80% of the reduction in emissions from individual heating by households will be attributable to a shift to other types of heating and due to a higher share of renewables in mains gas. The remaining around 20% will be due to energy efficiency improvements in heating consumption.

Energy efficiency improvements can reduce heat losses, for example, and thus reduce the demand for input heat. Heat losses were reduced from 20% to 12% in the period 1990 to 2021. Specifically, this means that, in 1990, one-fifth of the energy input for

[26]There are data and methodological changes relative to CSO22. With regard to methodology, in CSO22, buildings for which the heating technology was unknown were counted under district heating, whereas in CSO23, these buildings have been grouped together in their own separate group called 'Unknown'. With regard to data, in CSO23, the number of oil-fired boilers has been assessed at somewhat higher than in CSO22. This is due to updated figures on the number of addresses to which oil has been delivered. Furthermore, the number of heat pumps has been adjusted slightly upwards compared with Statistics Denmark's data. Due to these differences, data in CSO22 and CSO23, respectively, cannot be directly compared.

space heating production and domestic hot water in households was wasted. By 2030, this heat loss will have been reduced to 7%, according to the projection.

3.4 Uncertainty

The household sector comprises many different actors with different preferences. Choice of heating technology depends on how individual households weight the cost of installation, use and maintenance, respectively. Just as geographic location (in a district heating area or not) has significance for the options available.

Moreover, preferences change over time in ways which can be difficult to predict. Overall trends are the sum of many individual choices and are therefore exceedingly difficult to project.

Furthermore, municipal heating supply plans can also influence the number of households with the option to change to district heating. Municipal heating supply plans will likely be included in estimates for CSO24.

Finally, there is uncertainty about the heating technology data in the Danish Building and Dwelling Register, as well as uncertainty about the projection of parameters that are crucial for future energy consumption, such as number of households, number of heated square metres, etc.

4 Transport sector

Unless we cycle or walk, all transport is linked with energy consumption, and this influences our energy system and thus potentially also emissions of greenhouse gases. Developments in the transport sector and in transport sector emissions are partly driven by the many very different needs to transport people and goods, partly by current regulations and policy measures in the area, and partly by technological developments.

The transport sector includes both private and public passenger transport as well as freight transport divided into the following categories:[27]

- Road transport
- Rail transport
- Domestic aviation
- Domestic shipping
- Other transport (Danish Defence and leisure craft).

In 2019, the transport sector emitted 13.5 million tonnes CO_2e. The Covid-19 pandemic reduced the demand for transport, and, as a result, emissions fell to 12.6 million tonnes

[27] Domestic aviation and shipping include domestic routes as well as routes between Denmark and Greenland and the Faeroe Islands, respectively. In accordance with the UN IPCC methodology, emissions from international aviation and shipping are not included in the Danish climate accounts. However, these emissions are described in Global Report 2023, which is published in parallel with CSO23.

CO_2e in 2021. The projection projects emissions to fall additionally up to 2035, see table 1.

Table 4.1: Total transport sector emissions

Million tonnes CO_2e	2019	2021	2025	2030	2035
Total transport sector emissions	13.5	12.6	12.2	10.5	8.2
- of which road transport	12.4	11.6	11.2	9.6	7.3
- of which domestic shipping	0.5	0.6	0.5	0.5	0.5
- of which rail transport	0.2	0.2	0.2	0.0	0.0
- of which domestic aviation	0.1	0.1	0.1	0.1	0.1
- of which other	0.2	0.2	0.2	0.2	0.2

Note: Figures in the table are rounded and summing of emissions from individual transport categories may deviate from total transport sector emissions.

The projection shows that total transport sector emissions will be at 10.5 million tonnes CO_2e by 2030, corresponding to 36% of total Danish emissions, and that emissions will fall additionally to 8.2 million tonnes CO_2e by 2035.

As can be seen from table 4.1, road transport accounts for far the majority of total emissions from the transport sector. Developments in road transport depend in particular on the following factors:

- Growing traffic (number of kilometres driven will increase)
- Electrification of road transport through transition from conventional to electric vehicles
- Renewable fuels blending[28] in petrol and diesel
- Energy efficiency improvements in new conventional vehicles.

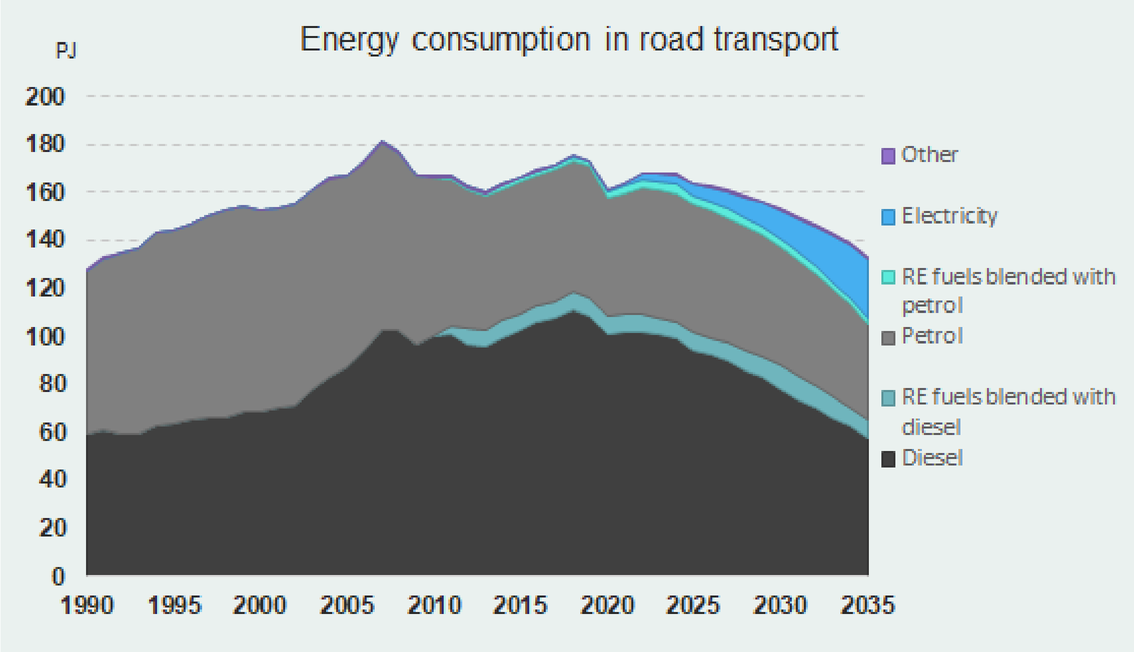
Despite ever increasing road transport traffic, the projection shows that emissions will fall as a consequence of electrification, higher blending ratios for renewable fuels, and more efficient conventional vehicles.

4.1 Transport sector emissions

Figure 4.1. shows the development in total greenhouse gas emissions by the transport sector broken down by transport category for the period 1990-2035.

[28] In the memorandum, renewable fuels (fuel produced on the basis of renewable energy sources) is an overall term for biomass-based fuels (e.g., bioethanol and biodiesel) and fuel produced using electrolysis (PtX technology).

Figure 4.1: Transport sector emissions 1990-2035 in CO_2e by type of transport



All emissions from the transport sector are from the sector's use of energy. The projection shows that total sector emissions will decrease faster than projected in CSO22, in particular in the years from 2030 to 2035. In 2030, transport sector emissions are projected to be around 0.25 million tonnes CO_2e lower in CSO23 than in CSO22.

Below are descriptions of emissions from road transport, rail transport, domestic aviation and domestic shipping, respectively.

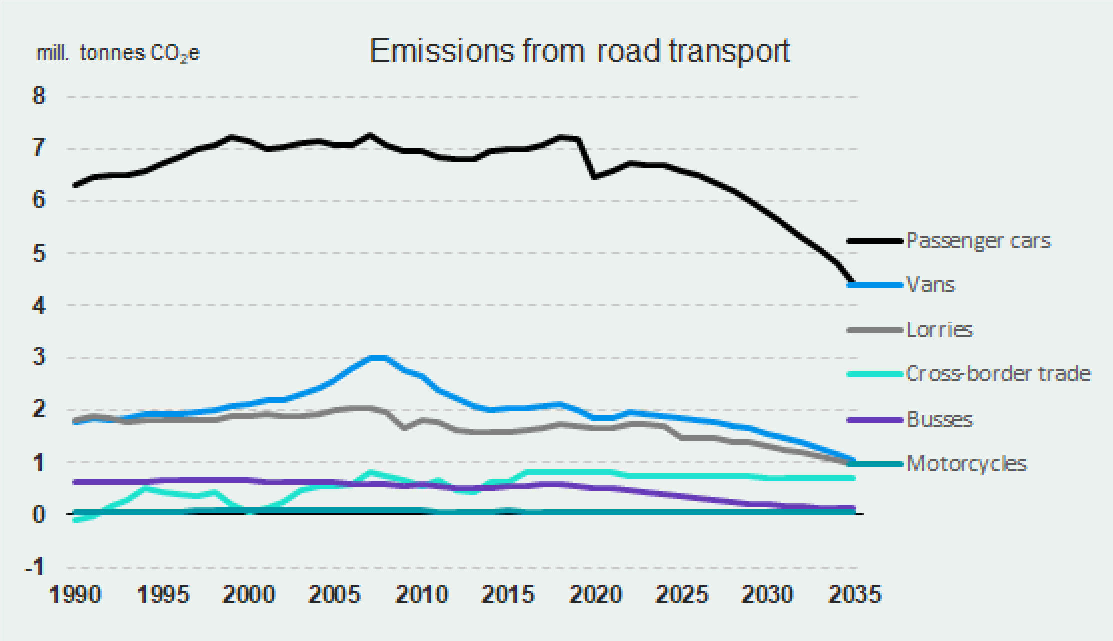
Emissions from road transport

Road transport is responsible for by far the majority of emissions from the transport sector. In 2019, road transport emitted 12.4 million tonnes CO_2e, corresponding to 92% of total emissions by the transport sector. Emissions fell during the Covid-19 pandemic and were at 11.4 million tonnes CO_2e in 2020 and 11.6 million tonnes CO_2e in 2021. The projection shows an increase in emissions again in the wake of the pandemic, but after this, emissions are projected to decrease significantly in spite of continuous growth in demand for road transport. By 2025, emissions will have fallen to 11.2 million tonnes CO_2e, and by 2030 and 2035 they will have fallen to 9.6 million tonnes CO_2e and 7.3 million tonnes CO_2e, respectively.

Cars account for the largest share of emissions from road transport, at 57% in 2021, followed by vans and lorries.

This is described in figure 4.2, which shows greenhouse gas emissions from road transport, broken down by type of vehicle and cross-border trade.[29] Cars are also the category for which the projected decrease in emissions is greatest in absolute figures.

Figure 4.2: Emissions from road transport by vehicle, 1990-2035



Despite a continued increase in traffic, the projection shows a reduction in emissions of greenhouse gases from all vehicle types. This is attributable to vehicle electrification, higher blending ratios for renewable fuels and continued energy efficiency improvements in conventional vehicles. The trend in vehicle electrification is described in more detail in section 4.3.

Emissions from rail transport

In 2019, rail transport emitted 0.2 million tonnes of CO_2e, corresponding to around 2% of emissions by the transport sector. Despite an expected expansion of train operations, a considerable reduction is projected in emissions after 2025 in step with the electrification of inter-city and regional trains, as these are responsible for most emissions. In 2030, emissions from rail transport are projected to be 0.02 million tonnes CO_2e; a mere tenth of today, and in 2035, there will be no emissions at all. The last diesel trains are expected to be phased out just after 2030.

[29] In accordance with the UN IPCC methodology, emissions associated with cross-border trade in fuel are included in the country where the vehicle refueled. Emissions from cross-border trade (i.e. the fuel tanked up in Denmark but consumed abroad) are calculated separately and maintained at the 2019 level in the projection period. Note that this is an estimated level, as cross-border trade cannot be calculated exactly.

Emissions from domestic aviation

Emissions from domestic aviation were 0.15 million tonnes CO_2e in 2019, corresponding to around 1% of total transport sector emissions. As a result of the Covid-19 pandemic, emissions from domestic aviation were 0.08 million tonnes CO_2e in 2020 and 0.09 million tonnes CO_2e in 2021. It is assessed that activity in the sector will increase gradually as a result of increased demand for domestic flights. It is expected that activity in the sector will not return to the pre-pandemic level until 2025. Furthermore, the projection includes an expectation that the incrementally increasing CO_2 tax on fuels for domestic aviation under the *2022 green tax reform for industry etc. agreement*, which enters into force from 2025, will put a damper on developments in activity. The projection also expects general energy efficiency improvements. The projection shows that emissions from domestic aviation will increase to 0.13 million tonnes CO_2e in 2025 and 0.14 million tonnes CO_2e in 2030, after which emissions will remain unchanged. Renewable fuels blending is not assessed to be financially feasible without further regulation of the sector, and use of renewable fuels in domestic aviation has therefore not been included in the projection.

Emissions from domestic shipping

Emissions from domestic shipping accounted for 3.9% of total emissions by the transport sector in 2019. The projection shows that emissions will remain more or less constant at around 0.5 million tonnes CO_2e in the period up to 2035. However, the projection predicts a slight reduction in emissions as a result of electrification of a number of short ferry services, partly as a result of deployment of the pool to promote green transition of domestic ferries in 2021 (11 ferries received commitment of funding) and in 2022 (three ferries received commitment of funding). With the pool for green transition of domestic ferries, in 2021 and in 2022, 15 existing ferries were replaced by 14 green electric-powered ferries, either through refurbishment or new purchases. Furthermore, the introduction of a CO_2 tax as part of the *2022 green tax reform for industry etc. agreement* is assessed to increase the incentive to opt for electric ferries when buying new ferries. The projection does not include use of renewable fuels, such as ammonia or methanol in domestic shipping, because this is not assessed to be financially feasible without further regulation of the sector. Even with the introduction of the agreed CO_2 tax, renewable fuels are assessed to be associated with a considerable additional cost, including the cost of having to invest in infrastructure etc.

4.2 Transport sector framework conditions, etc.

A number of political agreements have been adopted since CSO22 with decisive importance for the likely development in transport sector emissions. This applies to road transport in particular, which is likely to be affected by, for example:

- The EU Regulation on CO_2 emissions reduction requirements for new passenger cars and for new light commercial vehicles (cars and vans): The emissions targets for new passenger cars and vans set out in the original Regulation (EU) 2019/631 have been tightened in accordance with the EU Fit for 55 package and Commission proposal 2021/0197 (COD). The revised Regulation requires car manufacturers to reduce average emissions from new cars and vans sold in the EU by 55% and 50%, respectively, by 2030 relative to the level in 2021, and by 100% by 2035 for both cars and vans. The requirement for a 100% reduction in emissions in practice means a ban on sales of new cars and vans with internal combustion engines[30] (including plug-in hybrids) in the EU from 2035. The effect of the 100% reduction requirement by 2035 has been included in the projection. The revised Regulation is assessed to lead to an acceleration in production and sales of electric cars and vans. Furthermore, the phase-in of electric vehicles will happen faster than in CSO22 and the electric vehicle sales share will reach 100% by 2035.

- The mileage-based road tax on heavy-duty vehicles agreement (agreement from June 2022): From 2025, a mileage-based road tax will be introduced on lorries in Denmark. The tax will be differentiated based on CO_2 emissions. The tax is expected to reduce and put a damper on traffic by lorries and increase the incentive to invest in electric lorries when old lorries need to be replaced. The agreement therefore contributes to less traffic and a higher share of electric lorries than indicated in CSO22.

Furthermore, 2025 will see the introduction of an incrementally increasing CO_2 tax as part of the *2022 green tax reform for industry etc. agreement*. The new tax transfers part of the existing fuel-based energy tax on road transport to a CO_2-based tax. The specifics of the new tax are still to be determined. However, according to the agreement, the new tax may not lead to a tax increase for petrol and diesel, and for this reason the projection does not include the effect of this part of the agreement. The agreement also covers fuels used for domestic shipping and aviation. For domestic shipping, the CO_2 tax is assessed to incentivise electrification of domestic ferries, while for domestic aviation, it will likely put a damper on developments in activity levels. For both domestic shipping and domestic aviation, the CO_2 tax is not assessed to have an

[30] The revised Regulation on CO_2 emissions reductions requirements opens for sales of cars with 100% e-fuel-powered internal combustion engines. This option is expected to cover only niche vehicles outside the main focus of the Regulation, and it will therefore not have an effect on overall developments.

effect on the use of renewable fuels, as it is not considered to provide enough incentive to increase the share of renewable fuels as a replacement for fossil fuels.

Note also that the projection does not consider the revision of the EU ETS for aviation, the decision to extend the ETS to include emissions from shipping from 2024, as well as the establishment of a separate emission trading system (ETS II) for road transport and buildings, all of which are part of the EU Fit for 55 package. No adequately specific agreement texts currently exist to allow for assessment and inclusion of possible effects.

4.3 Activity level, efficiency improvements and technology shifts in the transport sector

The drop in emissions of greenhouse gases from the transport sector shown in the projection are driven by developments in road transport. These developments are described in the following.

Developments in road transport activity

Road transport activity has been calculated in terms of traffic (number of kilometres travelled) and, according to the projection, traffic is expected to increase in line with general economic growth. The projection shows that total traffic for all road transport will increase by around 20% between 2021 and 2035. While traffic by passenger cars will increase by around 23%, the projection shows traffic by lorries will increase by significantly less: only around 5% over the period. This is attributable to the introduction of a mileage-based road tax on lorries in Denmark from 2025, which it is assessed will reduce traffic and put a damper on subsequent growth.

More zero-emission and low-emission vehicles in road transport

Passenger cars have seen technological and market developments that, in combination with a series of vehicle tax reductions, have led to considerable rises in sales of electric cars and plug-in hybrids in recent years.

2022 saw sales of slightly more than 30,000 new electric cars and slightly more than 26,000 new plug-in hybrids, corresponding to 21% and 18%, respectively, of new sales. This trend is projected to be amplified up to 2030 and 2035 as a result of the revised Regulation on CO_2 emission performance standards for new cars and vans.

According to the projection, sales of electric cars will increase to around 120,000 cars in 2030 and 290,000 cars in 2035, corresponding to around 55% of new sales in 2030 and almost 100% of new sales in 2035.[31]

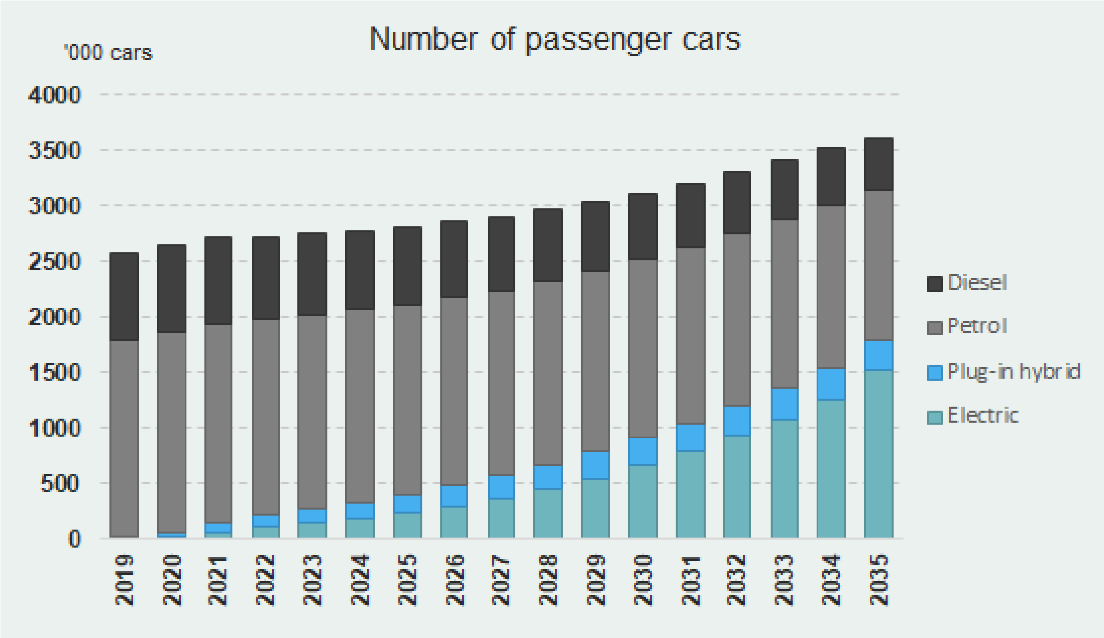
Sales of plug-in hybrids will fall throughout the projection period, primarily because of the phase-out of tax incentives for plug-in hybrids and an expected significant increase in the supply of electric cars. At the same time, the charging infrastructure and the average range of electric cars are expected to improve over time, so that a greater number of consumers can have their demands met by electric cars.
Furthermore, the revised Regulation on CO_2 emission performance standards for new cars and vans means that no more plug-in hybrids can be sold in the EU from 2035. The projection shows that sales of plug-in hybrids will comprise around 6% of new sales in 2030.

It is expected there will still be drivers with special preferences and special transport needs such as frequent long-distance journeys, for whom electric cars will be challenged on weight, range and price and for whom conventional technologies will therefore remain attractive. According to the projection, numerical sales of new diesel and petrol cars will remain more or less unchanged up to and including 2034, although their share of sales will fall. After this, entry into force in 2035 of the EU requirement for a 100% reduction in emissions from new vehicles will have an effect.[32]

Based on these assumptions, the breakdown of new cars by technology in the period 2019-2035 is as illustrated in figure 4.3. Note that the projection shows an abrupt increase in the sales share of new electric cars from 2034 to 2035 (and a correspondingly abrupt phase-out of other technologies). However, it is uncertain whether the development in the period up to and including 2034 will be slower than anticipated and whether the increase in the sales share will therefore be higher in 2035, or whether the new EU Regulation on CO_2 emission performance standards for new cars and vans will instead lead to a faster and more even increase in the sales share of electric cars towards 100% in 2035.

[31] Because sales of new cars refer to 0-year-old cars (i.e. both new registrations and imported 0-year-old used cars), the projection includes a very small sales share of conventional cars and plug-in hybrids in 2035, which are sales of imported used cars (and these must necessarily come from countries outside the EU because the EU Regulation on CO_2 emission performance standards for new cars and vans applies at EU level). This is a result of the assumption about developments in imports of used cars and the breakdown of these imports by technology.
[32] The projection of sales of new cars with internal combustion engines in the years up to 2035 is very uncertain. It can be argued that sales will fall because internal combustion engines will be considered outdated, linked to concern about lower resale value and high depreciation. However, it can also be argued that sales of conventional cars will increase because it will be the last chance to buy a new car with an internal combustion engine.

Figure 4.3: Sales of new cars by technology, 2019-2035



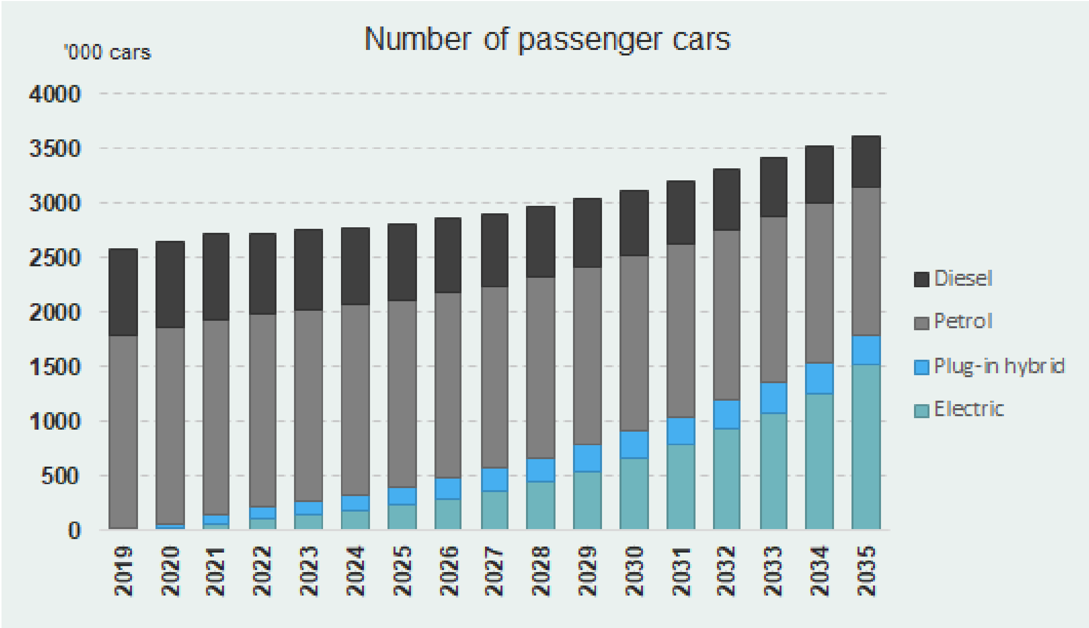
Source: Bilstatistik.dk (DBI IT A/S) for the years 2019 to 2022 (the data has been processed to fit with the Danish Energy Agency's segmentation).

As can be seen from figure 4.3, the projection also shows an increase in total sales. This is attributable to an assumed increase in car ownership in step with economic and population growth and in combination with passenger cars becoming relatively cheaper to own and use. Because of the revised Regulation on CO_2 emission performance standards for new cars and vans, there is significant uncertainty about the development in total sales of new cars, because the revised CO_2 performance standards (also referred to as CO_2 emission reduction targets or emission targets) may have various derived effects, for example with regard to used car imports and the average lifetime for conventional vehicles.[33]

The phase in of new passenger cars results in the projection illustrated in figure 4.4.

[33] However, there are several other factors that contribute to uncertainty about the development in total sales, including developments in car prices, consumer climate awareness, expansion of public transport, road infrastructure and parking options in towns and cities.

Figure 4.4: Number of cars by technology, 2019-2035



Source: Bilstatistik.dk (DBI IT A/S) for the years 2019 to 2022 (the data has been processed to fit with the Danish Energy Agency's segmentation).

The projection shows that, by 2030, the total number of cars will have increased to around 3.1 million, of which electric cars and plug-in hybrids are expected to comprise around 900,000, corresponding to almost 30% of the total number of passenger cars. Of the 900,000 electric cars and plug-in hybrids, 660,000 are electric cars, which means that electric cars will account for 20% of the total number of passenger cars in 2030.

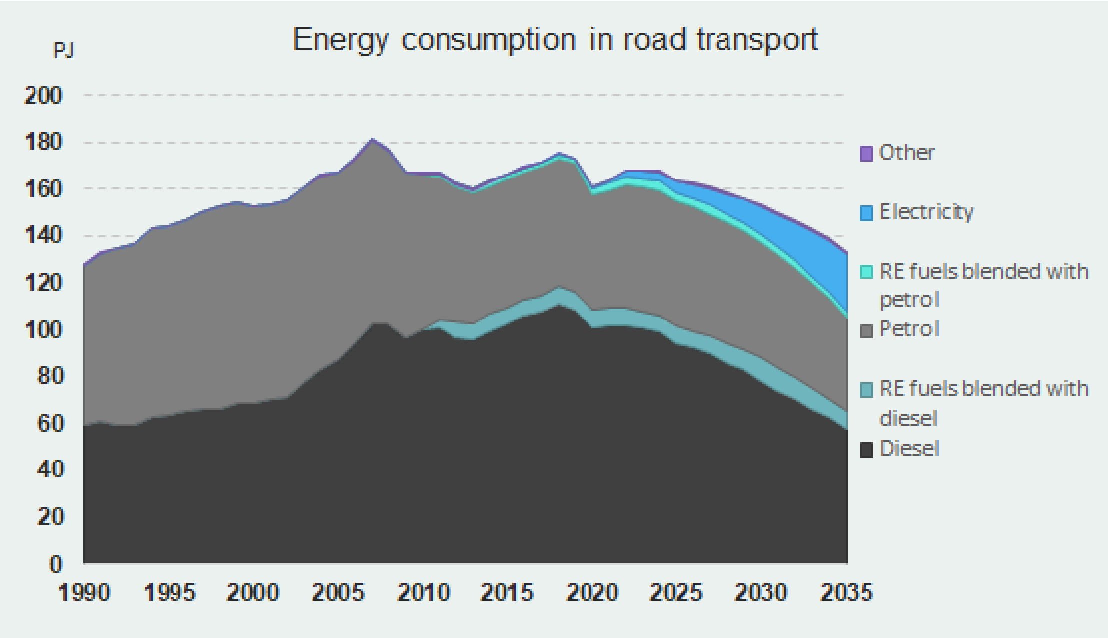
A similar development towards more electric vehicles is seen for the other categories of vehicle. For vans and lorries, the current trend is partly driven by the original Regulation on CO_2 reduction requirements for cars and vans and for heavy vehicles (lorries), which also contributes to improved fuel economy in new conventional petrol and diesel vehicles. The shift to electric lorries is expected to be amplified by the mileage-based road tax to be introduced on lorries in Denmark. The tax will be differentiated based on CO_2 emissions. The projection shows that sales of electric vans will make up 100% of new sales in 2035, while electric lorries will make up around 50% of total sales of new lorries (corresponding to 42% of the total number of vans and 21% of the total number of lorries).

Note that there is large uncertainty associated with the projection of total sales of new vehicles, how sales break down by technology, and, thus, with the total number of vehicles in future years.

Energy consumption in road transport

Energy consumption by road transport is a product of activity in the sector combined with the energy efficiency of the vehicles. Previous efficiency improvements in conventional vehicles have not been sufficient to compensate for increasing traffic, and this has resulted in increased energy consumption. However, because electric vehicles are more energy efficient than conventional vehicles, this trend will stop during the projection period and energy consumption will fall up to 2035, as shown in figure 4.5 According to the projection, total energy consumption by road transport will fall from about 173 PJ in 2019 to 153 PJ in 2030 and 133 PJ in 2035. Much of the energy consumption will be from renewable fuels as a result of a Danish CO_2e-displacement requirement, which will gradually be tightened towards 2030, see CSO23 sector memorandum 4B.

Figure 4.5: Energy consumption in road transport by energy product 1990-2035



4.4 Uncertainty and sensitivity analyses

The 2035-year projection of energy consumption and emissions in the transport sector is associated with significant uncertainty. It is difficult to give an overall assessment of the uncertainty because the projection is based on a number of assumptions that may pull the development in opposite directions. The overarching factors driving transport sector energy consumption and associated emissions are developments in traffic volume, transitioning to new and more energy-efficient technologies, including zero-emission and low-emission vehicles, as well as use of renewable fuels. To illustrate the significance of these factors for emissions, a number of sensitivity analyses have been performed concerning the phase-in rate for electric cars (passenger cars) and electric lorries, as well as trends in overall road transport traffic.

Despite recent years' increase in sales of electric cars and consensus among experts and car manufacturers that electric cars will drive the clean energy transition of passenger cars, there is still great uncertainty associated with the rate of the transition. To illustrate the significance for emissions, two alternative sales scenarios have been calculated for electric cars. An accelerated scenario, in which the transition to electric cars is faster than in the basic scenario, and a delayed scenario, in which the transition is slower than in the basic scenario. Both scenarios assume compliance with the Regulation on CO_2 emissions reduction requirements, including realisation of the requirement for 100% reduction in emissions from new cars in 2035.
In the accelerated scenario, the sales share of electric cars reaches 68% in 2030, while in the delayed scenario it reaches 40%. Relative to the CSO23 basic scenario, the alternative phase-in scenarios for electric cars lead to a reduction in emissions of around 0.13 million tonnes CO_2e in 2030 and 0.66 million tonnes CO_2e in 2035 in the accelerated scenario, and an increase in emissions of 0.42 million tonnes CO_2e in 2030 and 0.95 million tonnes CO_2e 2035 in the delayed scenario. The effect on emissions in 2025 is minimal because replacing the total car fleet takes a relatively long time.

The sensitivity analyses and associated effects are described in more detail in CSO23 sector memorandum 4A.

5 Service sector

The service sector includes the private service sector, the public service sector and wholesale and retail. The private service sector covers a broad range of sectors, including restaurants, banks and data centres, while the public service sector includes day-care centres, schools, hospitals and public administration. Retail and wholesale includes all trade, from supermarkets to car dealers, etc.

By far the majority of energy consumption by the sector is electricity and district heating, the emissions from which are described under the electricity and district heating sector in chapter 8, while emissions linked to transport are described in the chapter on transport. The remaining emissions from the service sector described in this chapter today therefore mainly stems from mains gas used for individual heating, although previously there have also been considerable emissions of F gases.

In 2021, the service sector emitted 0.8 million tonnes CO_2e, corresponding to just under 2% of total Danish emissions. The projection shows that the sector will emit 0.4, 0.2 and 0.1 million tonnes CO_2e, respectively, in 2025, 2030 and 2035, corresponding to around 1% of total Danish emissions in 2025 and less than 1% in both 2030 and 2035.

Changes in sector emissions are due in particular to the following factors:

- Phase-out of mains gas through conversion to heat pumps for space heating
- An increasing renewables share (biomethane) in mains gas, which lowers emissions from the remaining mains gas consumption.

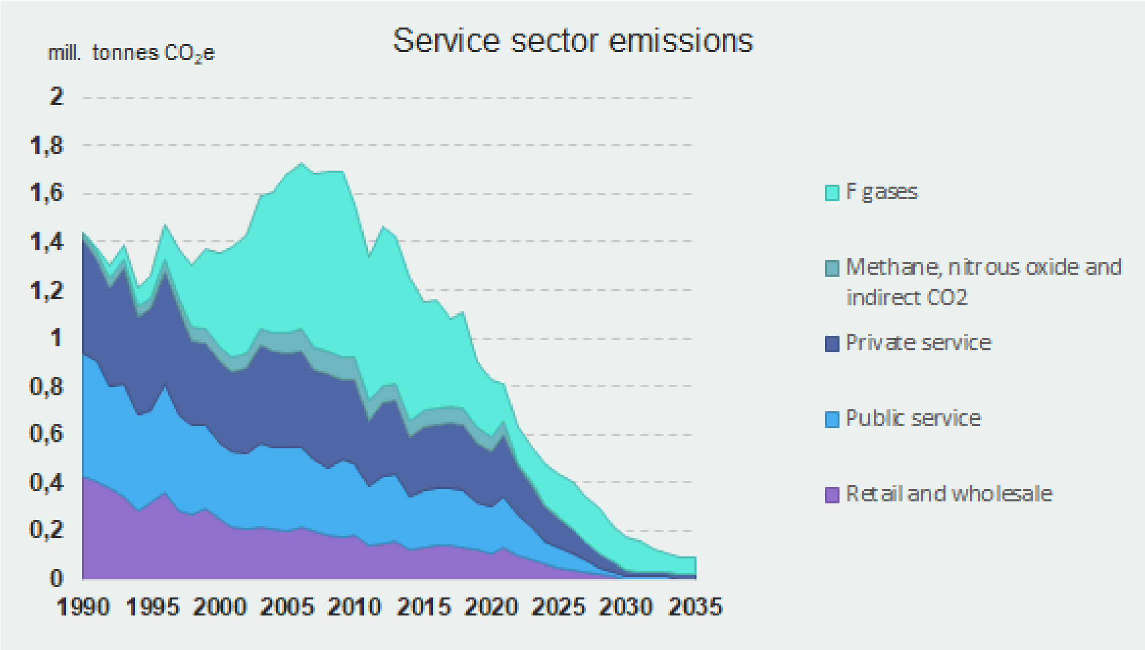
Data centres fall under the private service sector and are currently expanding considerably. Data centres will lead to significant increases in electricity consumption by the service sector in 2030, but the emissions associated with this are included in chapter 8 on the electricity and district heating sector, as also applies for other electricity and district heating consumption by the sector.

5.1 Service sector emissions

Most of the sector's energy consumption is electricity consumption, while the sector's direct emissions today stem largely from fossil fuels used for space heating.

Total emissions by the service sector are illustrated in figure 5.1. Emissions from the sector include both energy-related emissions and F gases. Energy-related emissions include emissions from individual space heating, internal transport and process heat. The relatively low emissions should be seen in light of the fact that emissions derived from consumption of electricity and district heating are included in the calculation of emissions from the electricity and district heating sector.

Figure 5.1: Emissions from the service sector by sub-sector and F gases



The projection of total emissions by the sector indicates a fall to 0.2 million tonnes CO_2e in 2030 and to 0.1 million tonnes CO_2e in 2035. This corresponds to a decrease of

79% and 89% respectively compared with 2021. Up to today, reductions have been driven in particular by the shift from oil-fired heating to district heating, while expected reductions up to 2030 and 2035 are primarily due to an increasing proportion of renewable energy in mains gas and conversion from gas-fired boilers to heat pumps. In 2021, emissions from mains gas amounted to around 60% of total sector emissions. The projection shows that, in 2030, mains gas will be green, which means there will no longer be any emissions associated with the consumption of gas.

For 2025, the projection shows that 50% of emissions will stem from space heating, with by far the majority coming from mains gas. The remaining emissions in 2030 will primarily be F gases, and a small share of emissions from space heating and internal transport, while 2035 will almost only see emissions from waste incineration for space heating and in the form of F gases.

5.2 Service sector framework conditions, etc.

In addition to F-gas emissions, by far the majority of the sector's emissions come from space heating, although a small share of emissions come from process heat, an area in which 2022 saw the adoption of a number of political agreements that may affect energy consumption.

For the service sector, the political agreements included in CSO23 are:

- The *2022 climate agreement on green power and heating*
- The *green tax reform for industry etc. agreement*.

5.3 Activity level, efficiency improvements and technology shifts in the service sector

Even though the service sector does not account for more than 2% of total emissions, the sector uses 14% of total Danish final energy consumption, and this will increase to 21% in 2035.

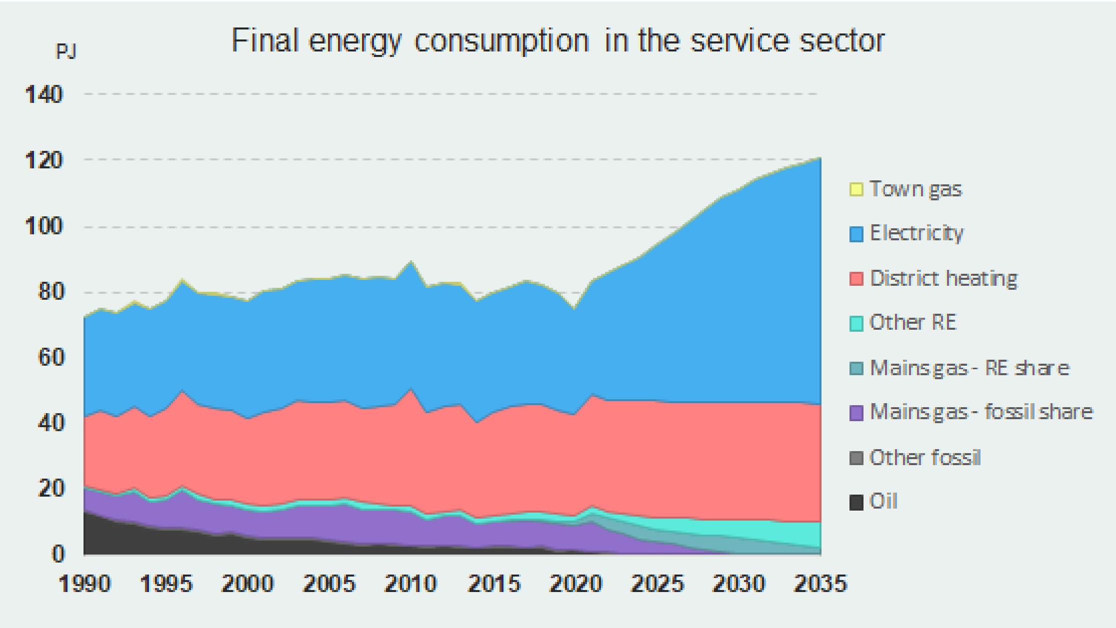
As can be seen in figure 5.2, the projection shows that final energy consumption in the service sector will increase from 84 PJ in 2021 to 121 PJ in 2035. Despite expected production growth within trade and private services, the increase in energy consumption by the service sector will mainly be due to establishment of data centres. This is because there is also expected increased energy efficiency, and this will offset some of the increase in energy consumption in the rest of the sector.

In 2021, just under 4 PJ of electricity was consumed by data centres in Denmark, but this is expected to increase to 28 PJ in 2030 and to 36 PJ in 2035

In trade, there is a large electricity consumption for lighting and for cooling and ventilation. In the private service sector, besides data centres, there is considerable electricity consumption within the restaurant sector, while schools, day-care centres and hospitals account for a substantial amount of electricity in the public service sector. Up to 2035, the projection shows a shift from mains-gas-based heating towards more district heating and heat pumps, which, together with the establishment of more data centres, will lead to higher electricity consumption.

In 2021, electricity accounted for 41% of the sector's final energy consumption. In the projection, this figure will have increased to 62% in 2035. This means that, with the current projection, the service sector will account for more than 40% of total final electricity consumption in 2035.

Figure 5.2: Final energy consumption in the service sector by energy product



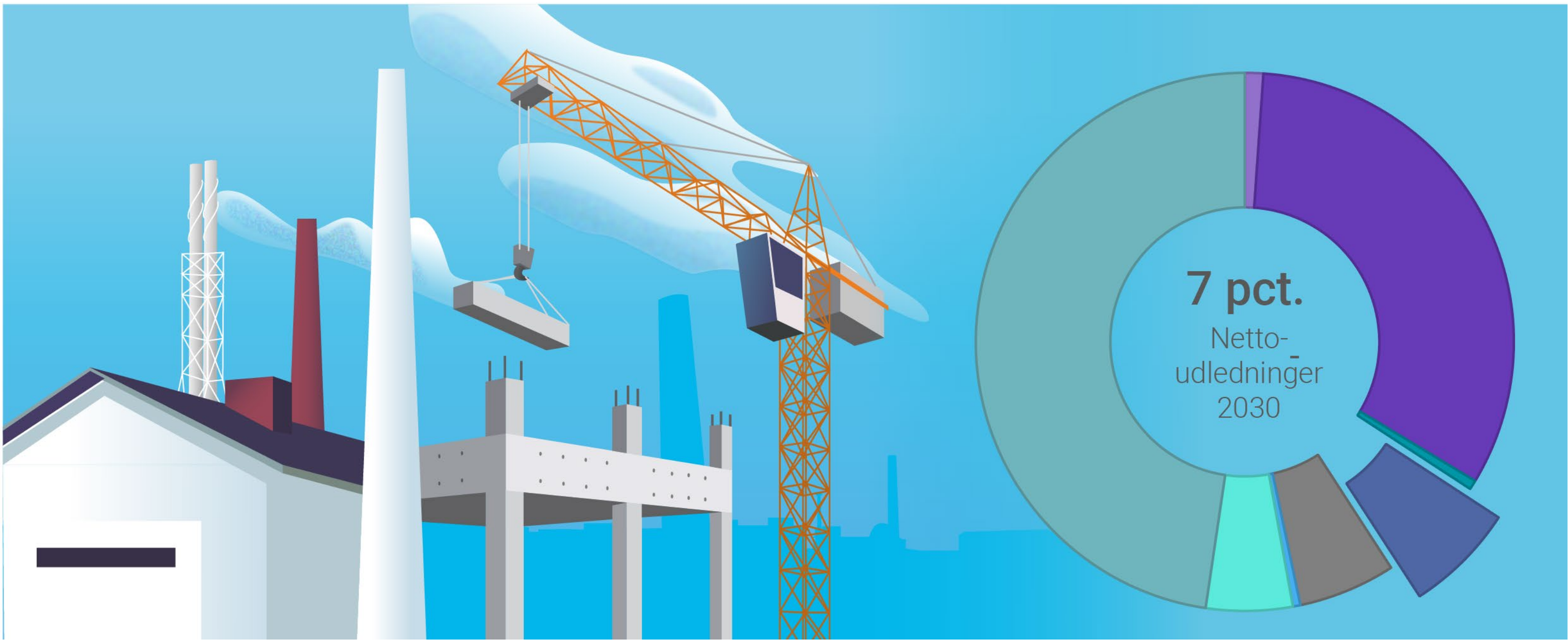
Mains gas makes up the majority of fossil-energy consumption by the service sector. Mains gas consumption by the service sector was 9 PJ in 2021 but is projected to fall to 5 PJ in 2030 and 2 PJ in 2035, when mains gas is expected to be renewables-based and carbon-free. The reduction in gas consumption is primarily due to conversion from gas-fired boilers to heat pumps.

5.4 Uncertainty

There is a particularly high uncertainty associated with the deployment of data centres within the service sector, as well as with future technological developments and their significance for the electricity demand and demand profile of data centres.[34] This does not, however, affect emissions from the service sector described in this chapter, because emissions from electricity production are dealt with under the electricity and district heating sector.

Furthermore, municipal heating supply plans can also influence the share of service sector entities with the option to change to district heating. Municipal heating supply plans will likely be included in estimates for CSO24.

[34]Read more about the assumptions used for the projection of electricity consumption in the CSO23 memorandum on assumptions on data centres.



6 Manufacturing industries and the building and construction sector

Manufacturing industries include businesses which produce goods sold to private individuals and other enterprises. These include food and textiles, furniture and electronic equipment, chemical and pharmaceutical products, building materials and machinery. Building and construction industries include businesses involved in all types of work within building and construction.

As illustrated in table 6.1, manufacturing industries and the building and construction sector emitted 5.3 million tonnes CO_2e in 2021, corresponding to around 11% of total Danish emissions. The projection shows that emissions by the sector will be 4.0, 2.1 and 2.0 million tonnes CO_2e, respectively, in 2025, 2030 and 2035, corresponding to 10-11% of total Danish emissions as total emissions are also set to fall up to 2035. The projected changes in sector emissions are due in particular to the following factors:

- More widespread electrification and higher energy efficiency, including more use of heat pumps for internal exploitation of surplus heat
- Increased renewables share in mains gas
- Drop in domestic cement production.

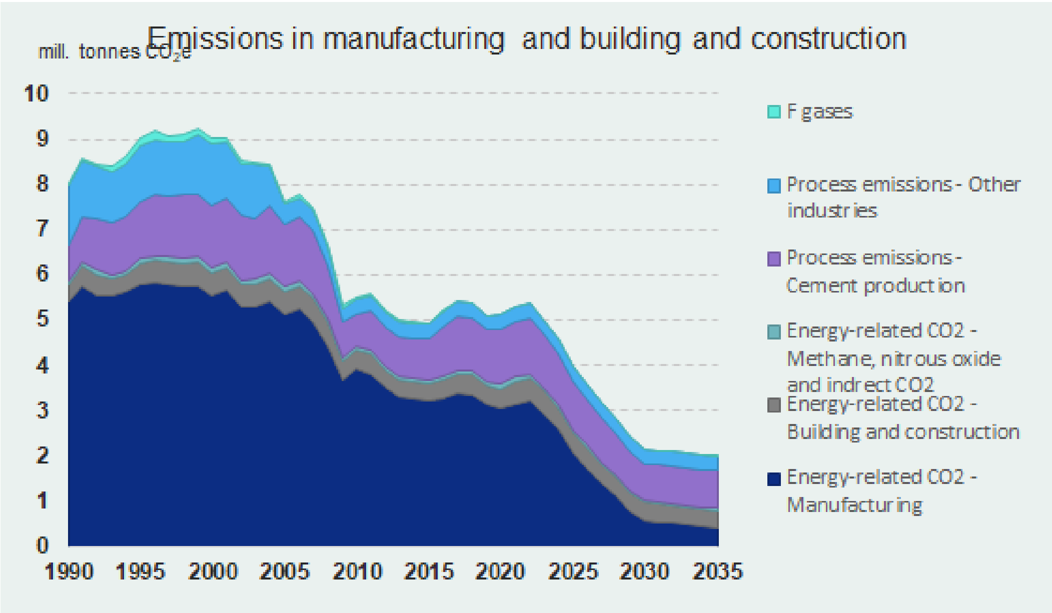
6.1 Emissions by manufacturing industries and the building and construction sector

Total emissions from the sector includes energy-related emissions, process emissions and a small amount of F gases. Process emissions are emissions that occur as the product of a chemical process in production. The manufacturing industries have a relatively large share of process emissions compared with other sectors. The largest source of process emissions is manufacturing processes in which clay, chalk and limestone are included as a raw material, for example production of cement and tiles through calcination at high temperatures.

Energy-related emissions are emissions resulting from using fossil fuels for production processes, including process heat and internal transport.[35]

The projection shows that the manufacturing and building and construction sector will achieve significantly larger annual CO_2e emissions reductions up to 2035 than hitherto. From 2021 to 2030, emissions will be reduced by more than 3 million tonnes CO_2e, corresponding to almost 60% or nearly 10% annually on average, see figure 6.1.

Figure 6.1: Emissions by manufacturing industries and the building and construction sector 1990-2035, in CO_2e



The projection also shows that emissions from manufacturing and building and construction are expected to be lower in CSO23 than in CSO22 across the period 2024-2035. The projection in shows higher emissions for the years 2022-2023 than in

[35]Emissions from consumption of electricity and district heating are not dealt with in this chapter, as they are included in the calculation of emissions from the electricity and district heating sector (see chapter 8).

CSO22. This is the consequence of the current shift from mains gas to coal and oil due to the relatively high prices of mains gas.

The following sections explain the background for developments in the sector's emissions, with special focus on the target years 2025 and 2030 and the projection's final year 2035.

6.2 Framework conditions for manufacturing industries and the building and construction sector

The projection shows that total emissions from manufacturing and building and construction are significantly lower than in CSO22. The is due to, for example, the *2022 green tax reform for industry etc. agreement*, which is set to impose a general CO_2 tax on ETS and non-ETS companies. The tax will be phased in from 2025 and up to 2030, when it will be fully phased in. The reform will provide a greater incentive to convert away from fossil fuels and to carry out energy efficiency improvements. It is also assumed the reform will give rise to structural changes in manufacturing industries, including, in particular, a large fall in domestic production of cement. (Danish Ministry of Taxation, 2023).

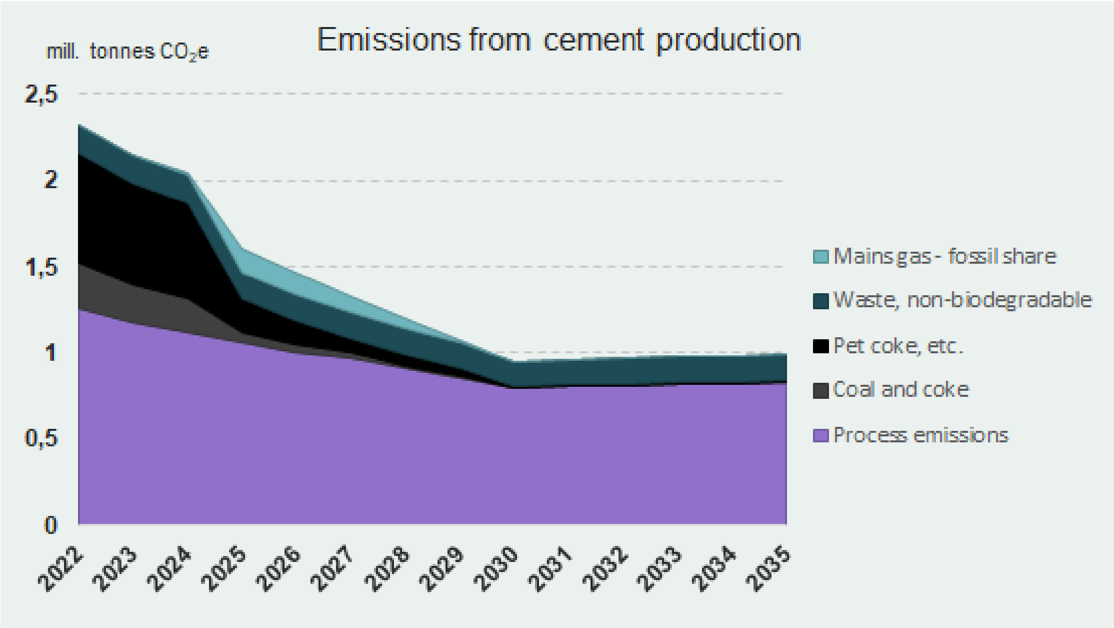
6.3 Activity level, efficiency improvements and technology shifts in manufacturing industries and in the building and construction sector

CSO23 projects emissions from manufacturing industries and building and construction industries to be reduced overall by 63% from 2022 to 2035. Energy-related emissions in particular will be reduced up to 2035. This is partly due to less consumption of oil and coal and more consumption of biomass and mains gas. Mains gas is assumed to be carbon-free by 2030. Furthermore, the projection shows that energy efficiency improvements and increased exploitation of surplus and ambient heat through heat pumps will lead to a reduction in energy-related emissions from the sector.

There are several factors behind the lower level of total emissions from manufacturing and building and construction industries in CSO23 compared with CSO22. The three most important factors are described below.

CSO23 assumes a more significant drop in cement production compared with CSO22, and this is due primarily to the structural effects of the *2022 green tax reform for industry etc. agreement*, which have been recognised in CSO23. From 2021 to 2030, cement production is therefore assumed to fall by about 32%. As a result, process emissions from cement production will be reduced from 1.2 million tonnes CO_2e in 2021 to 0.8 million tonnes CO_2e up to 2030. Furthermore, the projection shows that energy-related emissions from cement production will fall up 2030, from around 1 million tonnes CO_2e in 2021 to 0.15 million tonnes CO_2e in 2030. After this, emissions will remain at the same level up to 2035 and will stem primarily from burning fossil waste, see figure 6.2.

Figure 6.2: Emissions from cement production by fuel and process emissions



Finally, CSO23 also shows lower growth or zero growth in manufacturing industries and building and construction industries up to 2030 compared with CSO22, resulting in lower emissions from the sector.

6.4 Uncertainty and sensitivity analyses

Uncertainty in emissions from manufacturing industries and the building and construction sector includes uncertainty linked to activity levels. This applies in particular to cement production, which is assumed to be reduced considerably as a consequence of the *2022 green tax reform for industry etc. agreement*. A sensitivity calculation has therefore been performed assuming continued cement production at today's level in all sectors. More specifically, this assumes that cement production overall stays at the same level as in 2022, and that demand for energy services in other industries as a minimum is at the same level as was consumed in 2022.[36] Furthermore, a sensitivity analysis has been performed assuming a stop to domestic cement production replaced instead by imported cement to meet Danish demand. For other

[36] Energy services are defined on the basis of temperature and function, such as high-temperature process heat, space heating or motorised operations.

sectors, no sensitivity analyses have been performed assuming lower production than assumed in CSO23.

The results of the sensitivity analyses are presented in table 6.1 below and show that total emissions in the manufacturing and building and construction sector, with the above assumptions, are around 660,000 tonnes CO_2e higher if, as a minimum, production in the sector continues at the 2022 level. The table also shows that emissions from the sector will be around 950,000 tonnes CO_2e lower if cement production in Denmark ceases.

Table 6.1: Emissions in manufacturing industries and building and construction industries compared with a sensitivity analysis, assuming continued production at today's level and a stop to domestic production of cement

Unit: million tonnes CO_2	CSO23	CSO23 continued production	CSO23 ceased cement production
Total for manufacturing and building and construction	2.14	2.68	1.19
Manufacturing (excl. cement production)	0.80	0.98	0.80
Cement production	0.95	1.27	0
Building and construction	0.39	0.43	0.39

7 Production of oil, gas and renewable fuels

A number of different fuels are extracted and produced in Denmark, including fossil oil and gas as well as renewable fuels such as biogas, biofuels and PtX products.

The sector includes oil and gas extraction in the North Sea, refinery activities and the production of biogas, biofuels and PtX. In 2021, the sector emitted 2.5 million tonnes CO_2e, corresponding to 5% of total Danish emissions. The projection shows that in 2025, 2030 and 2035 the sector will emit 2.1, 1.9 and 1.8 million tonnes CO_2e, respectively. This is including recognition of the expected effect of methane loss regulation for biogas.

The expected changes in sector emissions are due, in particular, to the following factors:

- Commissioning of the Tyra complex, etc. means an increase in emissions from oil and gas extraction up to 2024
- Ageing oil and gas fields in the North Sea mean a drop in extraction of oil and gas, and thus in associated emissions
- Energy consumption and emissions by refineries are projected to fall as a result of the *green tax reform for industry etc. agreement*

- Higher methane losses from biogas production in the CRF estimate as a result of increased activity. However, due to the methane loss regulation, a reduction in methane losses will occur from 2024, after which emissions will increase again (in step with the expansion of production capacity), albeit from a lower starting point.

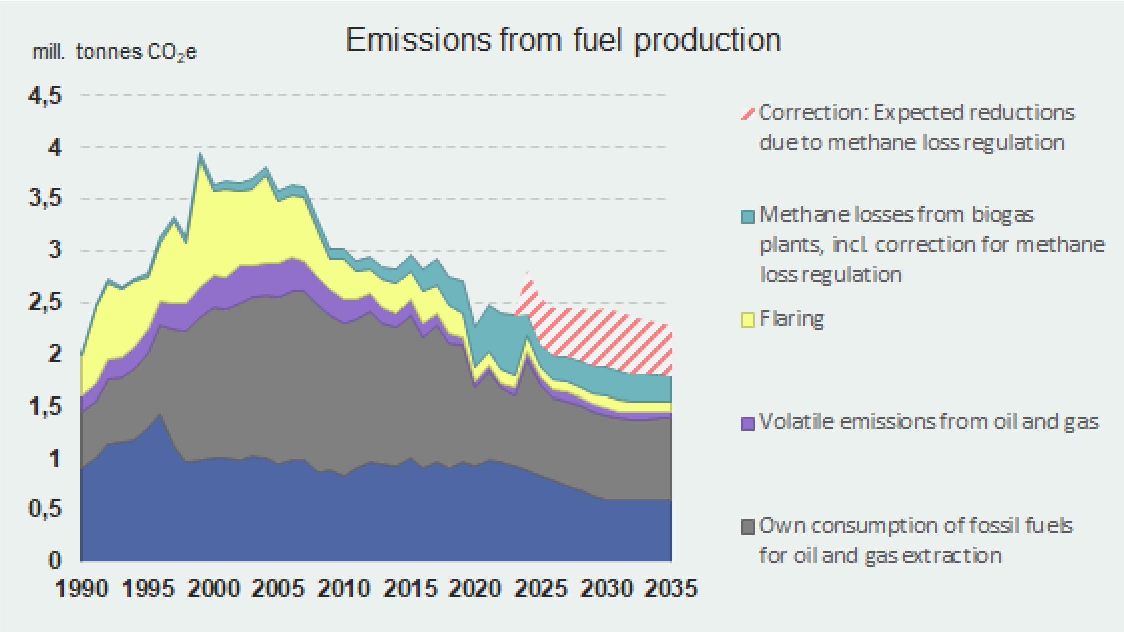
Furthermore, developments in energy consumption by the sector are also influenced by PtX deployments (in the form of electricity consumption for electrolysis). Greenhouse gas emissions associated with this energy consumption are dealt with under the electricity and district heating sector in chapter 8. Finally, biogas production has an effect on the renewables share in mains gas and thus on the displacement effect on greenhouse gas emissions from mains gas consumption, see chapter 2.

7.1 Emissions when producing fuels

The primary reason for emissions from this sector is own consumption of fossil fuels for oil and gas extraction in the North Sea and at refineries, as well as methane losses from biogas plants. Furthermore, a small part of the emissions is due to flaring, i.e. burning gas that, for safety or technical reasons, is not recovered on extraction platforms in the North Sea or at refineries. Finally, to a smaller extent, fuel production causes volatile emissions in the form of evaporation, spillage and leakages, etc.

The development in emissions by the sector for the period 1990-2035 is illustrated in figure 7.1. Falling emissions are observed throughout the 2000s, in particular because of falling emissions from flaring. Consumption of fossil fuels at refineries and drilling rigs constitutes the majority of emissions today and in the future. The reduction in emissions in 2020-2023 is due to redevelopment of the production platform by the Tyra field, which is therefore out of commission. The increased emissions in 2024 are linked partly to commissioning of the Tyra complex and partly to commissioning of a number of other, smaller projects, in which emissions are highest in the start of the operating phase. Up to 2035, extraction of oil and gas will fall due to ageing fields, and emissions from refineries are assumed to fall as a result of the introduction of a CO_2 tax as part of the *2022 green tax reform for industry etc. agreement*.

Figure 7.1: Emissions from fuel production by origin



Note: Own consumption of fossil fuels at refineries includes emissions linked to electricity and district heating production at the refineries. Emissions in the figure are based on the CRF estimates; i.e. emissions have not been corrected for the expected effect of methane loss regulation, but the expected reductions from this measure are illustrated in the figure.

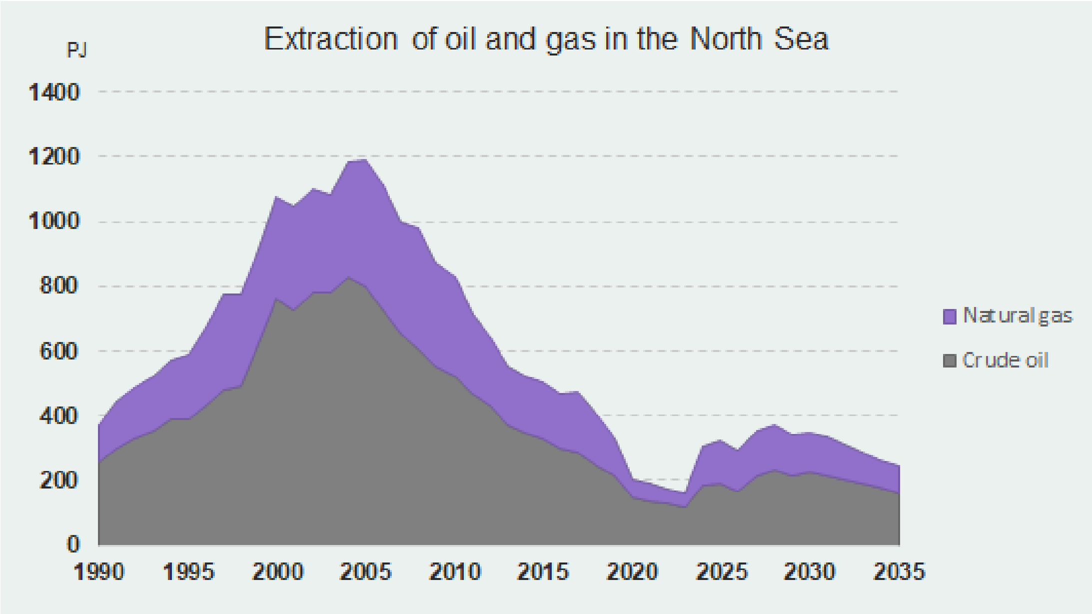
Extraction of oil and gas

Emissions associated with oil and gas extraction are linked to the activity level in the sector. Emissions from oil and gas extraction have been projected to be around 0.9 million tonnes CO_2e in 2030, falling to around 0.8 million tonnes CO_2 in 2035. Emissions from oil and gas extraction in the North Sea are due partly to energy consumption by platforms which today primarily have their demand covered from natural-gas-fired gas turbines, and partly by flaring. Gas consumption on the platforms is based on natural gas, i.e. exclusively fossil gas, as opposed to mains gas, which is a blend of biomethane and natural gas. Figure 7.2 shows the expected development from 1990 to 2035 and shows that, in 1990, extraction of oil and gas from the North Sea was at about 370 PJ, then the activity increased and peaked at around 1,200 PJ/year in the mid-2000s, after which a downward trend is seen.

Extraction of oil and gas is expected to increase up to 2028, amongst other things due to the redevelopment of installations in the Tyra field and commissioning of a number of other, smaller projects. After 2028, extraction is expected to fall due to ageing fields. According to the oil and gas production forecast for the North Sea, it is expected that just under 80 PJ of gas and just under 165 PJ of oil will be extracted in 2035.

Denmark has been a net gas exporter since the mid-1980s, and it is expected this will stay the same throughout the projection period, except in the years 2021-2024 due to redevelopment of the installations in the Tyra field. On the other hand, Denmark has been a net importer of oil since the mid-2010s, and this is expected to continue throughout the projection period.

Figure 7.2: Extraction of oil and gas in the North Sea



Refineries

Emissions from refineries have been projected to be around 0.6 million tonnes CO_2e in 2030 and in 2035. CSO23 estimates emissions from energy consumption by refineries to fall as a result of smaller production as well as a shift in production in response to the introduction of a CO_2 tax, see the memorandum on sector assumptions on oil and natural gas extraction and refineries. In the most recent historical period, activity has increased slightly. However, the emissions linked to this increase in activity have been offset by continuous efficiency improvements. As can be seen from figure 7.1, emissions from refineries are estimated to follow a downward trend up to 2030, after which they are estimated to remain constant throughout the rest of the projection period. In CSO23, expectations about production and shifts in production at refineries follow the partial effect estimated in the *2022 green tax reform for industry etc. agreement*. The agreement is expected to lead to a 29% decline in production at refineries by 2030, and a shift towards more energy efficiency improvements and use of green alternatives to own consumption of refinery gas ("Documentation and sensitivity analyses of effects for industry and for space heating", February 2022).

Biogas production

Greenhouse gas emissions from the biogas sector mainly comprise methane losses (leakage) from biogas plants. The loss rate has been estimated at 2.9% for biogas plants and 6.9% for wastewater treatment plants, see CSO23 sector memorandum 7B on biogas, PtX and renewable fuels.

The *climate agreement on green power and heating* introduced a regulation scheme for methane losses from biogas plants. The scheme entered into force on 1 January 2023. As stated above, the effect of this scheme has not been included in the CSO23 CRF estimate, but has been partially deducted in the emissions gap estimates etc. The calculation of the effect of methane loss regulation in CSO23 assumes that all biogas plants will reduce their methane losses to 1% from 2024, which means that methane losses from biogas production will be reduced to 0.2 million tonnes CO_2e in 2025, 0.3 million tonnes CO_2e in 2030 and 0.2 million tonnes CO_2e in 2035.

Note that the scheme only requires upgrading plants to reduce methane losses to 1% from 2024, whereas biogas plants are required to reduce losses 'as much as possible'. This means that the expected effect of methane loss regulation is uncertain because biogas plants will have to identify and plan remediation of any sources of methane loss, for example. In 2025, a measurement project will be performed to document the actual effect of the methane loss regulation scheme.

PtX

In CSO23, PtX is only included in the form of electrolysis capacity to produce green hydrogen. Any further conversions to other e-fuels such as ammonia and methanol are not included in CSO23. CSO23 assumes electrolysis capacity deployment to reach around 700 MW by 2025, around 900 MW by 2030 and around 1650 MW by 2035. Hydrogen production by electrolysis has been projected to be at around 10.8 PJ in 2030 and 20.3 PJ in 2035. Electricity consumption for electrolysis has been projected to be around 16.3 PJ in 2030 and 29.8 PJ in 2035.

7.2 Framework conditions, etc. for production of oil, gas and renewable fuels

Changes in framework conditions since CSO22 include the *green tax reform for industry etc. agreement* as well as an increase in fuel prices and in the EU emission allowance price. Finally, 2022 also saw the introduction of a *climate agreement on green power and heating,* which adjusts the framework conditions for biogas production.

- The *green tax reform for industry etc. agreement* introduced a CO_2 tax on emissions from extraction activities in the North Sea and from refineries of DKK 75 per tonne of CO_2 from 2025, increasing to DKK 375 per tonne in 2030. These activities have hitherto been tax exempt. With regard to extraction from the North Sea, the agreement was concluded after the licence holders had reported their expectations for the forecast. However, the forecast is based on licence holders' assessments of the future, including the effect of policies" known at the time of the assessment.

For refineries, the activity level has been estimated on the basis of the calculated structural effects included in the *2022 green tax reform for industry etc. agreement*. The calculated structural effects in this agreement are based on the same modelling methodology as the expert committee for a green tax reform applied in their first sub report on a possible green tax reform. The structural effect for refineries can be said to reflect the probability of production shutdown. In consultation with the Danish Ministry of Taxation, it has been decided to include the structural effect in the basic scenario as a percentage reduction in production relative to the expected linear baseline before the agreement (Danish Ministry of Taxation, 2023).

- For extraction of oil and gas in the North Sea, as well as for refineries, increased energy prices could mean higher earnings and, thus, increased production incentive. The increase in energy prices happened after estimation of the partial effects of a green tax reform. This could affect the probability of production shutdown at refineries. However, CSO23 does not include this effect for refineries.

- In the *climate agreement on green power and heating* it was decided to advance the six tendering rounds for subsidised production of green gases agreed as part of the *2020 climate agreement for energy and industry, etc.*, as well as to reduce the subsidy pool by around DKK 30 million. Furthermore, it was decided to introduce a regulation scheme for methane losses from biogas plants to enter into force on 1 January 2023. The expected effect of this scheme has not been included in the CRF estimate but has been partially recognised in the emissions gap estimates etc., see CSO23 sector memorandum 7B on biogas, PtX and renewable fuels.

- The *agreement on development and promotion of hydrogen and green fuels* (PtX Strategy) introduced a series of measures to promote the production of renewable fuels. These measures have been included in CSO23 through an overall assessment of all measures. Note that several of the measures are considered supportive measures that are still being concretised or are pending realisation of support capacities.

- Furthermore, the *agreement on development and promotion of hydrogen and green fuels* and the *2022 climate agreement on green power and heating* are expected to improve the framework conditions for increased deployment of renewable energy and electrolysis capacity (PtX). Access to sufficient quantities of green electricity is one of several important prerequisites for establishing a functional PtX market.

7.3 Activity level, efficiency improvements and technology shifts

Extraction of oil and gas

The oil and sales gas production forecast, and the forecast for own consumption and flaring, include the direct and indirect effects of the *agreement on the future for gas extraction in the North Sea* from 3 December 2020. The direct effects of the agreement on the oil and gas production forecast only concern potentials in relation to exploration and technology. There are also the indirect effects of the agreement, including a further reduction of the technology and exploration contribution in the most recent oil and gas production forecast forming the basis for figures related to own consumption and flaring in CSO23. This is due in particular to an expected reduced incentive to develop new technology as a result of the stipulation in the North Sea Agreement of an end date for extraction in 2050.

Refineries

According to the *green tax reform for industry etc. agreement,* the introduction of a CO_2 tax will lead to a 29% reduction in activity at refineries in 2030. The expected fall in activity means a fall in refineries' own consumption of fossil energy and related emissions. Furthermore, the agreement is assumed to lead to increased electrification and increased use of renewable fuels, thereby reducing emissions additionally up to 2030 compared with CSO22.

Biogas production

As a consequence of the altered framework conditions for biogas production, the projection assumes that activity in the sector will increase earlier than in CSO22, in that subsidies will be distributed earlier than expected. However, the cut in the subsidy pool means that the overall activity level is projected to be lower than in CSO22, see chapter 3 of the CSO23 memorandum on sector assumptions on *production* of oil, gas and renewable fuels. This reduces the projected methane losses from biogas production.

The projection also assumes that the increased activity as a result of tendering rounds for subsidised production will be realised through expansion of biogas production capacity. However, it cannot be ruled out that a part of this activity will manifest as efficiency improvements in existing production, for example e-methanation, see chapter 3 of the CSO23 memorandum on sector assumptions on production of oil, gas and renewable fuels.

PtX

Due to the new framework conditions for production of renewable fuels through PtX, as well as new commitments of funding, including through EU financing, the projection assumes higher production of hydrogen than previously expected.

Furthermore, the projection assumes that growing demand for PtX products, likely from abroad, will help propel a continued increase in deployment of PtX in Denmark up to 2035.

The scenario deviates from the target capacity of 4-6 GW by 2030 stipulated in the *agreement on development and promotion of hydrogen and green fuels* from 15 March 2022. This deviation is because establishment of several of the announced projects relies on necessary changes being made to the existing framework conditions, and therefore these projects have not been included in CSO23. Other factors assessed to be important to support a trajectory towards meeting the target of 4-6 GW PtX by 2030 include: concrete measures to stimulate demand for PtX products, altered tariffs and direct pipelines, as well as other improved framework conditions and a political decision on framework conditions for a hydrogen infrastructure.

7.4 Uncertainty and sensitivity analyses

Oil and gas extraction

There is general uncertainty about expectations for oil and gas extraction, and this uncertainty increases with the time horizon. For example, there is uncertainty linked to whether the higher prices of fossil fuels will increase the incentive to extract oil and gas from the North Sea, which could increase extraction activity and, thus, emissions.

Refineries

The projection of energy consumption by refineries is associated with some uncertainty, in particular in light of the effect of the green tax reform and of the higher prices of refined oil products as a result of the war in Ukraine.

The reduction in production for refineries can be said to reflect of the probability of production shutdown. The probability of shutdown has been included as a 29% reduction in activity in 2030. As an alternative to translating the estimated probability of shutdown to an actual reduction in production, it could instead be assumed that refineries will either produce at around full capacity or have no production at all. Therefore, three sensitivity analyses have been performed. One analysis in which refineries continue production at today's level, and two alternative analyses in which it is assumed that one of the refineries shuts down, either in 2025 or in 2030.

If production continues at today's level, emissions from own consumption will be at 0.9 million tonnes CO_2e in 2025 and 0.8 million tonnes CO_2e in 2030, compared with 0.8 and 0.6 million tonnes CO_2e, respectively, in the SCO23 basic scenario. If a refinery is shut down in 2025, emissions will fall to 0.5 million tonnes CO_2e in 2025, whereas shutdown of a refinery in 2030 will lead to emissions from own consumption of fuels of 0.4 million tonnes CO_2e in 2030.

Biogas production

In addition to the uncertainty described in section 7.1 about the estimated effect of methane loss regulation, the projection of biogas production is also associated various other uncertainties. For example, there is uncertainty with regard to the rate of deployment of new production capacity and utilisation of existing installations, as well as how all of this affects total activity in the sector. For a review of how these uncertainties affect the projection of biogas production see chapter 3 of the CSO23 memorandum on sector assumptions on production of oil, gas and renewable fuels.

8 Electricity and district heating

In CSO23, the electricity and district heating sector includes the majority of installations that supply Danish society with electricity and district heating, although not waste incineration plants, which are dealt with as part of the waste sector in chapter 9.[37]The sector includes CHP units that supply both electricity and district heating, wind turbines and photovoltaic modules that generate electricity, as well as boilers, solar heating and heat pumps that supply district heating.

In 2021, the electricity and district heating sector (excluding waste incineration) emitted about 5.0 million tonnes CO_2e, corresponding to 10% of total Danish emissions. In 2025, 2030 and 2035, the sector is expected to emit 1.1, 0.1 and 0.1 million tonnes CO_2e, respectively, corresponding to 3%, 0.4% and 0.4%, respectively, of total Danish emissions in the years in question. The expected changes in sector emissions are due to several factors, including:

- phase-out of the last coal-fired CHP plants,
- continued deployment of wind power and photovoltaic modules,

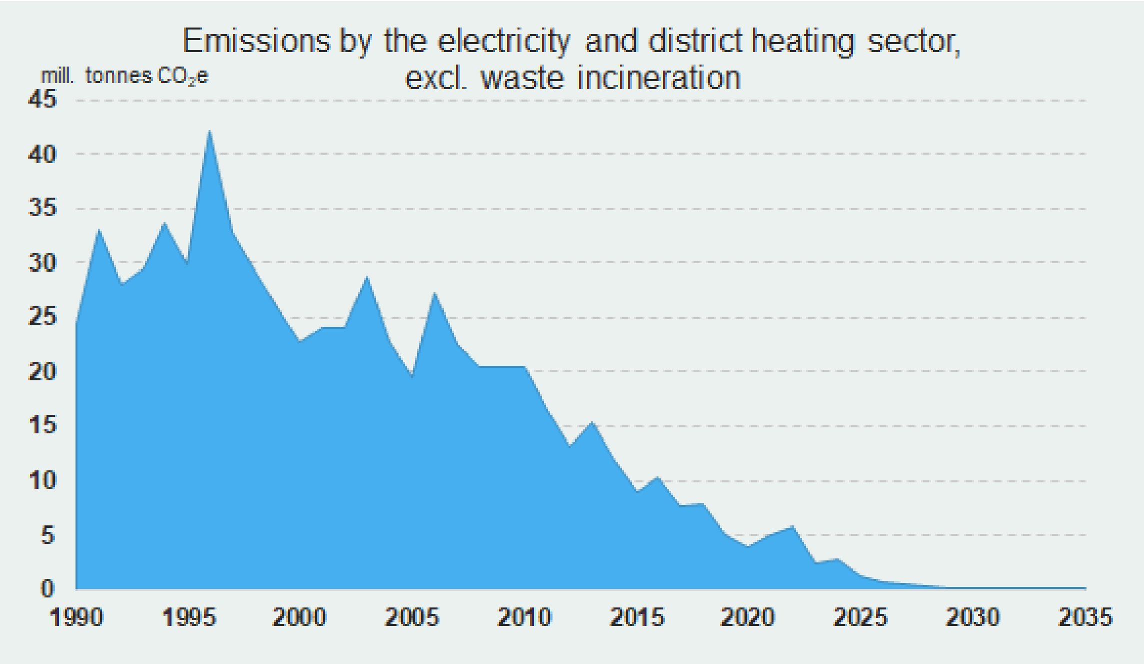
[37] Waste incineration plants also supply electricity and district heating, but in CSO23 these are dealt with as part of the waste sector in chapter 9. Furthermore, there are a number of autoproducers, who also contribute to electricity and district heating production. Autoproducers are producers whose primary product is not energy. For example, autoproducers include CHP units in the industry and service sector. In CSO23, energy consumption and associated greenhouse gas emissions from autoproducers are dealt with under the sectors to which the producers belong.

- significant further deployment of heat pumps to produce district heating, and
- reduction in CHP production based on mains gas.

8.1 Emissions from the electricity and district heating sector

Total emissions by the electricity and district heating sector for the period 1990-2035 are illustrated in figure 8.1 below. Emissions from the sector only include energy-related emissions (CRF-1) derived from the combustion of fossil fuels such as coal, oil and natural gas.

Figure 8.1: Emissions from the electricity and district heating sector, excluding waste incineration, in the period 1990–2035 (CO_2e)



As figure 8.1 shows, from 1990 to today the electricity and district heating sector moved from having large greenhouse gas emissions to having a significantly smaller climate footprint. This trend is expected to continue in the projection period up to 2035 and emissions from the sector will fall to around 0.1 million tonnes CO_2e in 2030, corresponding to a reduction of 99% compared to 1990. This means that, although in 1990 the sector was an important part of the climate challenge, in the future it will very much be part of the solution, as the electricity and district heating produced on the basis of renewable energy is expected to play an important role in reducing the climate impact of other sectors. Electricity consumption is therefore expected to increase significantly in the projection period up to 2035.

The following sections explain the background for developments in the sector's emissions, with special focus on the target years 2025 and 2030 and the final year 2035.

8.2 Electricity and district heating sector framework conditions

Three political agreements were established during 2022 that affect the framework conditions in the electricity and district heating sector:

- *The green tax reform for industry etc. agreement* from 24 June 2022
- *The climate agreement on green power and heating* from 25 June 2022
- The *additional agreement on Energy Island Bornholm* from 29 August 2022.

The *green tax reform for industry etc. agreement* includes a decision on higher and more uniform CO_2 taxes through reorganisation of energy taxes as well as introduction of a floor price for the CO_2 tax. The new effect of the new CO_2 tax on electricity and district heating production has been included in CSO23.

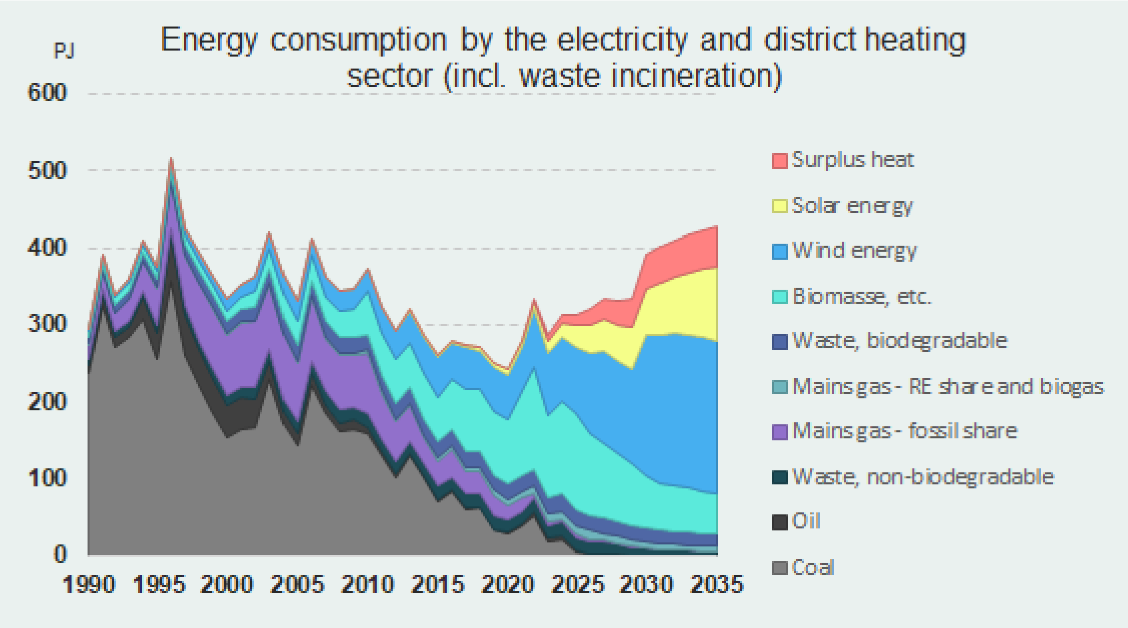
The *2022 climate agreement on green power and heating* includes a decision to tender sites for construction of an additional minimum of 4 GW offshore wind capacity before the end of 2030. Contracts will be awarded on the condition that the offshore wind farms do not adversely affect state finances during the project period and that there is the necessary capacity in the electricity grid. CSO23 does not include the additional 4 GW of offshore wind power in the basic scenario, but this has been included in an alternative scenario. The partial sensitivity analysis with the alternative scenario shows a marginally different effect on CO_2 emissions in Denmark's climate accounts. The *climate agreement on green power and heating* includes several measures with relevance for the electricity and district heating sector and these have been included implicitly in the assumptions about the deployment of renewable energy. See the relevant memorandum on sector assumptions on electricity and district heating for a description of how the projection depends on these measures.

The 2022 *additional agreement on Energy Island Bornholm* forms the basis for the political agreement between Denmark and Germany to connect Energy Island Bornholm to Germany. Establishing this interconnector is a precondition for inclusion of Energy Island Bornholm in the CSO23 basic scenario. The agreement also included a decision to increase the capacity of Energy Island Bornholm to at least 3 GW. The 3 GW consist of 2 GW agreed under the *2020 climate agreement for energy and industry, etc.* from 2020 (1 GW from windfarm 3 from the *2018 Energy Agreement,* and 1 GW out of the 2 GW agreed under the 2022 Finance Act).

8.3 Activity level, efficiency improvements and technology shifts in the electricity and district heating sector

The continuing decrease in emissions from the electricity and district heating sector is thus not because of falling activity in the sector, but rather it is due to a fundamental restructuring of the way in which electricity and district heating are produced. As shown in figure 8.2 below, developments in the electricity and district heating sector are characterised by an almost full transition to renewable energy, and this is primarily a result of phasing-out coal-fired cogeneration at large-scale plants, conversion to biomass, and continued deployment of onshore and offshore wind power and solar PV.

Figure 8.2: Energy consumption by the electricity and district heating sector, by type of energy (PJ)



Overall, consumption of fossil fuels for electricity and district heating production will be reduced by around 73%, 99% and 99%, respectively, by 2025, 2030 and 2035, respectively, compared to consumption in 2020. According to the projection, the reduction in consumption of fossil fuels including the non-biodegradable share of waste will be reduced by around 56%, 83% and 91%, respectively, by 2025, 2030 and 2035, respectively, compared to consumption in 2020. In future, Danish electricity production will therefore primarily be based on solar and wind energy, and the remaining share of electricity and district heating production will largely be biomass-based. Fossil fuels will only be for peak periods and as a reserve and as co-firing (support fuel), and this will be amplified by the renewables share of mains gas increasing further and reaching 100% in 2030.

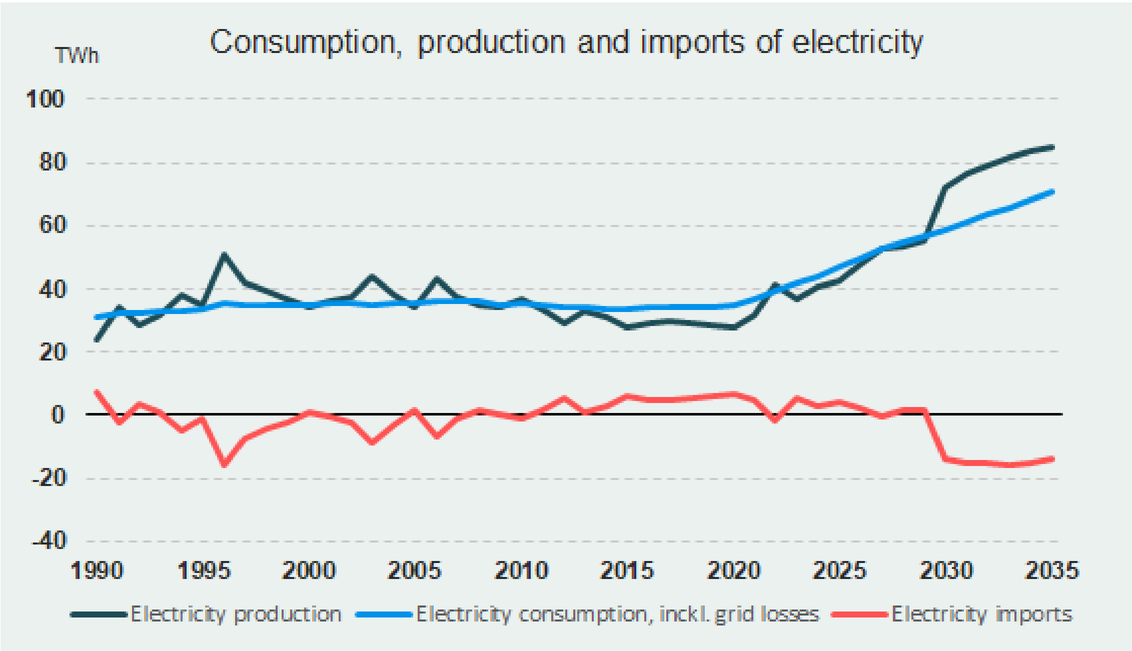
Sector interplay

Renewables-based electricity and district heating can supply other sectors and thus contribute to reducing their respective emissions. This could be either through direct electrification of transport, heating and industrial processes, for example, through conversion to district heating of buildings previously heated by mains gas, or through indirect electrification, for example through production of green synthetic fuels (PtX). However, this requires that increasing electricity consumption is accompanied by continued deployment of more renewable energy.

Electricity balance

The Danish electricity system is strongly integrated into the northern European electricity market, and historically the balance between domestic electricity production and electricity imports has fluctuated considerably, depending on conditions on the market, and these are affected by weather conditions such as precipitation, temperature and wind.

Figure 8.3: Electricity consumption, including transmission and distribution losses, electricity production and electricity imports



The projection shows that domestic electricity production will exceed domestic electricity demand in most years up to 2030. After 2030, the projection shows a surplus of electricity production due to considerable phasing in of additional renewable energy capacity, including the establishment of Energy Island Bornholm. However, the results are associated with significant uncertainty linked to several factors, both on the production side, for example uncertainty about the launch of future offshore wind farms and solar PV projects, and on the demand side, for example uncertainty about developments in electricity consumption by large data centres and PtX plants. Given meteorological fluctuations, it is likely that there will be years with net electricity exports, and years with the net electricity imports in the future too, but these fluctuations will have an increasingly weaker effect on emissions.

Fluctuating electricity production and demand-side flexibility

In a future where intermittent energy sources are expected to play an ever-greater role in electricity supply, ensuring continued renewable energy deployment to meet an increasing demand for electricity will not be the only challenge. It will also be a challenge to match supply and demand at all times, which can be achieved through increased flexibility on the demand side and interplay with all sectors involved.

CSO23 sector memorandum 8B on electricity demand describes how a significant part of the expected increase in electricity demand will stem from electric cars and heat pumps, and this demand could be more flexible than traditional electricity demand. Another significant part of the increase in electricity demand stems from data centres, the electricity demand of which is nearly constant throughout all hours of the year. Traditional demand accounted for about 90% in 2019. In the projection, this share will be reduced to around 65%, 50% and 40%, respectively, in 2025, 2030 and 2035. The projected mix in electricity demand therefore looks significantly different up to 2030 and 2035. Electricity demand for transport, electrolysis and partly also for district heating supply can also respond more flexibly to the fluctuating electricity production from wind and solar than traditional demand.

8.4 Uncertainty and sensitivity analyses

Because of the very high share of renewables in electricity and district heating production, the uncertainty in the projection pertains to a lesser extent to future greenhouse gas emissions and primarily to the scope and pace at which the sector will be able to contribute to the transition in other sectors. For example, variations in precipitation, temperature and winds have previously had a considerable effect on emissions from the electricity and district heating sector, with variations of +/- 5 million tonnes CO_2e. However, towards the end of the projection period, emissions from the sector are expected to be considerably less sensitive to intermittent weather. In 2030, therefore, variations in precipitation, temperature and wind will result in variations in the range of only +/- 0.1 million tonnes CO_2e.

The most important uncertainties are linked to the framework conditions for the sector, such as fuel and CO_2 allowance prices, renewable technologies prices following from rising raw material prices, developments in electricity consumption, planning aspects related to domestic offshore wind, onshore wind and solar PV deployment, as well as changes in the composition of electricity production capacities abroad. Furthermore, there is uncertainty about future investments in the district heating sector, for example linked to uncertainty concerning price developments for heat pumps and similar.

CSO23 sector memorandum 8A on the electricity and district heating sector includes more sensitivity analyses. The section below only describes how the projection, and the electricity balance in particular, could be affected if the North Sea Energy Island and the 4 GW from the *climate agreement on green power and heating* from 25 June 2022 (offshore wind farms under the government's *Denmark Can Do More II* reform initiative) are included in the projection. There is also a description of how the projection could be affected if Energy Island Bornholm is not realised.

Alternative scenario with additional offshore wind

This alternative scenario is not included in the CSO23 basic scenario. The system and climate consequences of the additional offshore wind for the Danish electricity and district heating sector have therefore been examined through a partial sensitivity analysis, in which it is assumed that the North Sea Energy Island will be connected to the grid in 2033 and the 4 GW offshore wind farms under Denmark Can Do More II will be connected to the grid before the end of 2030, while domestic electricity consumption will remain unchanged.[38]

In the sensitivity analysis with additional offshore wind, the renewables share in electricity consumption increases from 117% to 131% in 2030, and from 118% to 162% in 2035. A renewables share in electricity consumption of more than 100% means that, Denmark is expected to have a surplus of green electricity. This can be used to reduce greenhouse gas emissions from other sectors through direct or indirect electrification, or to displace fossil electricity production in countries neighbouring Denmark.

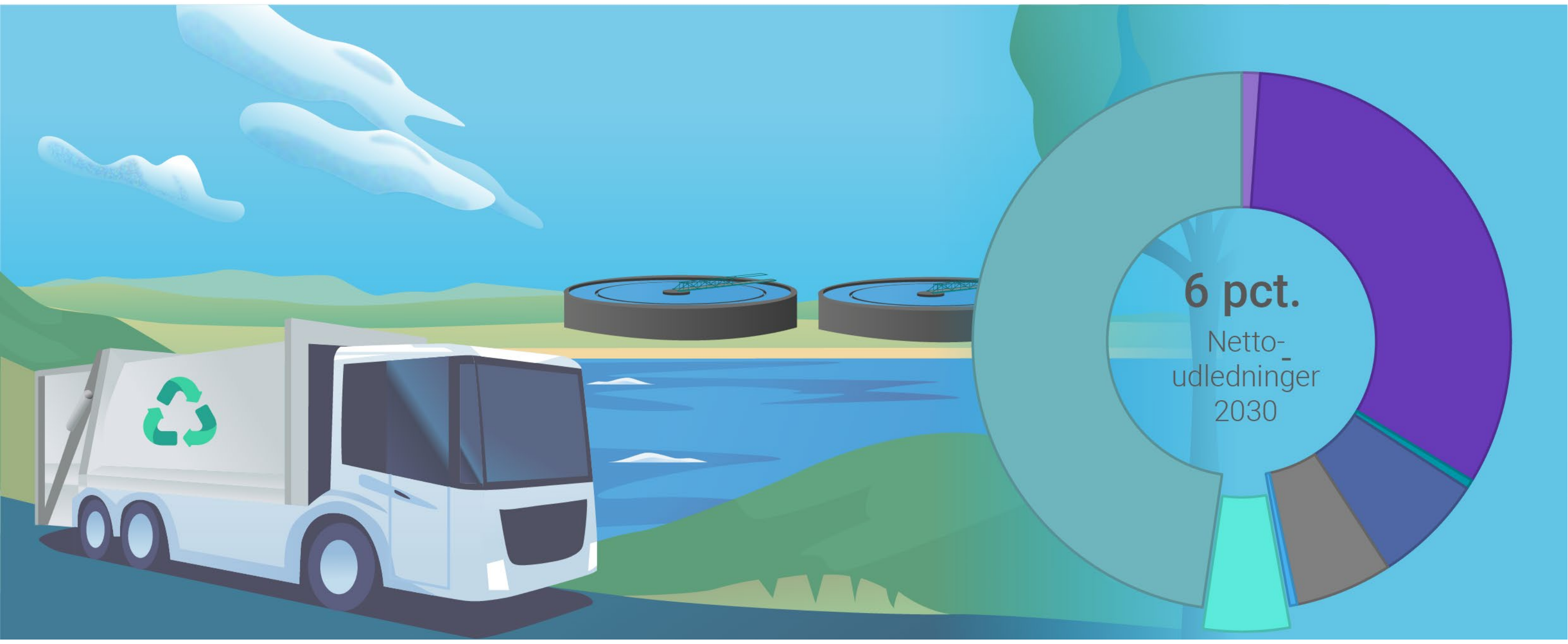
The sensitivity analysis also shows that, on their own, the energy islands have only very little direct significance for Danish emissions of greenhouse gases.[39] The reason for the small effect on Danish emissions is that there is already very little fossil-based electricity production in Denmark. However, the additional offshore wind from the North Sea Energy Island and the offshore wind farms under Denmark Can Do More II are expected to have a positive climate impact within the European electricity system, as Danish electricity exports will displace fossil-based electricity production abroad, just as the additional offshore wind capacity will make it possible to meet new domestic electricity demand, for example to produce green synthetic fuels (PtX), which can displace fossil fuels in other sectors.

[38] CSO23 sector memorandum 8A contains a description of the assumptions behind the partial alternative scenario with additional offshore wind.
[39] The effect on Danish CO_2 emissions towards the end of the projection period is assessed to be - 0.02 million tonnes CO_2e, see CSO23 sector memorandum 8A.

Partial alternative scenario on the supply side with deployment of fewer gigawatts offshore wind

To examine the effect of less offshore wind capacity in the Danish electricity system, an alternative scenario *without* Energy Island Bornholm has been analysed. Energy Island Bornholm is included in the basic scenario with 3 GW from 2030. The establishment of Energy Island Bornholm includes the establishment of two new electricity interconnectors: one to east Denmark and one to Germany. The alternative scenario is also *without* these interconnectors.

The alternative scenario shows no significant differences in greenhouse gas emissions. However, the alternative scenario shows a fall in the renewables share in electricity consumption (RES-E). In the alternative scenario, the renewables share is 104% and 102%, respectively, in 2030 and 2035, as opposed to 117% and 118%, respectively, in the CSO23 basic scenario. Thus, if Energy Island Bornholm is not realised, there will be a smaller surplus of green power in Denmark.



9 The waste sector (including waste incineration)

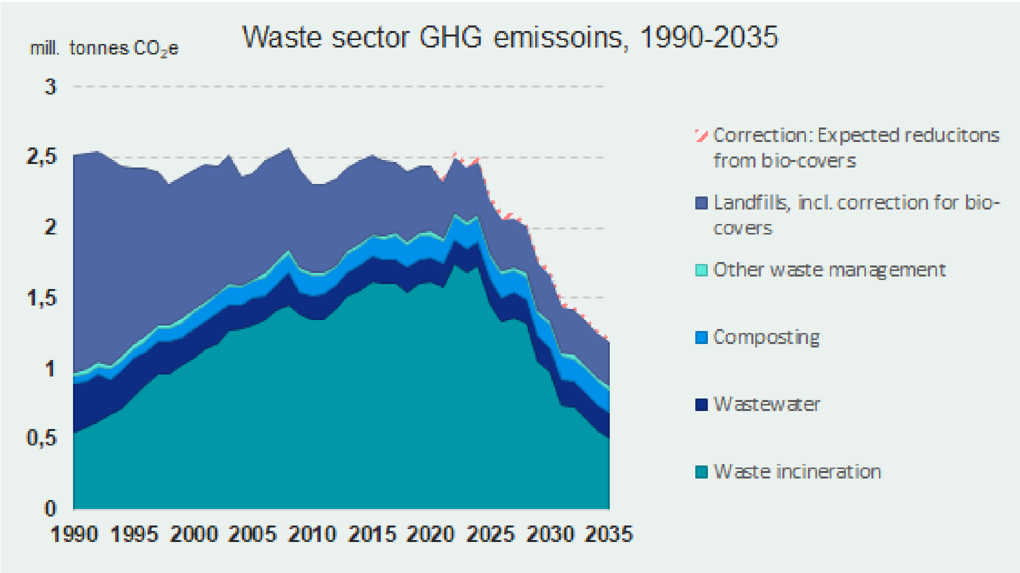
In CSO23, the waste sector includes treating waste and wastewater from households, the service sector and industries as well as composting garden and parkland waste. The sector emitted around 2.3 million tonnes CO_2e in 2021, including correction for the expected effect of bio-covers. In 2025, 2030 and 2035, the sector is expected to emit 2.2, 1.7 and 1.2 million tonnes CO_2e, respectively, corresponding to 6 and 5% of Danish emissions. These emissions depend on the volumes and types of waste in question, including how the waste is treated. The expected changes in sector emissions and changes relative to CSO22 are due, in particular, to the following factors:

- New impact assessment of capacity adjustments in the waste incineration sector as a consequence of deregulation (see the Waste Incineration Sector Restructuring, etc. Bill)
- New projection of waste volumes and waste treatment options as a consequence of the *follow-up agreement on a climate plan for a green waste sector and circular economy*
- Revised data basis for landfill waste volumes.

9.1 Waste sector emissions

Characteristic of the waste sector is that it disposes of the residual products from other sectors' consumption and production of goods and services. Depending on its properties, the waste is prepared for recycling, converted to energy or landfilled. Most of the waste can be recycled, however around 33% of the waste is incinerated, and over the past ten years the resulting energy production has covered around 20% of Denmark's total heating supply and 4% of final electricity consumption. The waste sector is therefore closely interlinked to the electricity and district heating sector, which are described in chapter 8.

Figure 9.1: Waste sector greenhouse gas emissions, 1990-2035 (million tonnes CO_2e)



Note: Expected emissions from waste incineration have been calculated excluding the expected effect of the *green tax reform for industry etc. agreement* from 2022. Emissions in the figure are based on the CRF estimates; i.e. emissions have not been corrected for the expected effect of bio-covers, but the expected reductions from this measure are illustrated in the figure.

Total emissions by the sector for the period 1990-2035 are illustrated in figure 9.1.

Emissions from the sector include both energy-related emissions from waste incineration (CFR-1) and waste-related emissions (CFR-5) stemming from landfilled biological waste, composting and wastewater treatment. The energy-related emissions are mostly CO_2, whereas the waste-related emissions are primarily methane and nitrous oxide.

The projection shows that the sector's total emissions will fall from around 2.3 million tonnes CO_2e to 1.2 million tonnes CO_2e in the period 2021 to 2035.

Compared with CSO22, the projection shows a reduction in the sector's emissions of 0.3 million tonnes CO_2e in 2025, an increase of around 0.2 million tonnes CO_2e in 2030 and a reduction of around 0.1 million tonnes CO_2e in 2035.[40] Note that the data basis for landfill waste volumes has been revised for CSO23. The revision means a reduction in greenhouse gas emissions from landfill of around 0.1 million tonnes CO_2e annually because of a lower historical baseline.

9.2 Waste sector framework conditions, etc.

Three political agreements were established during 2022 that affect the framework conditions in the waste sector:

- the *follow-up agreement on a climate plan for a green waste sector and circular economy*
- the *agreement on extended producer responsibility for packaging and disposable products*
- the *agreement on privatisation of municipal waste management services*

The *follow-up agreement on a climate plan for a green waste sector and circular economy* stipulates renewed time limits for municipal near-household textile-waste collection. Furthermore, it stipulates framework conditions for stricter oversight of waste management activities to ensure waste separation and increased recycling of industrial waste, as well as price-cap regulation of municipal waste taxes. On the basis of this, the Danish Environmental Protection Agency has updated its projection of waste volumes and waste management in Denmark. The tightened framework conditions are expected to reduce the volume of Danish waste suitable for incineration by around 330,000 tonnes in 2030 relative to CSO22.

The *agreement on extended producer responsibility for packaging and disposable products* stipulates framework conditions and principles for future producer responsibility. Producer responsibility was included as an instrument in the *climate plan for a green waste sector and circular economy* and the effect of this instrument has therefore been recognised in Denmark's Climate and Outlook reports since CSO21. Specification of the framework conditions has not given rise to any changes in assumptions relative to CSO22.

Under the *agreement on privatisation of municipal waste management services* municipalities will no longer have operational responsibility and customer relationship responsibilities in the waste area. The objective of the agreement is to eliminate the

[40] In CSO22, the waste sector covered greenhouse gas emissions in the form of methane losses from biogas plants. In CSO23, these emissions have been included in chapter 7 and have therefore been deducted from CSO22 waste sector emissions.

distortion of competition between private and municipal suppliers of waste services, and it is not assessed to have a direct impact on the climate.

9.3 Activity level, efficiency improvements and technology shifts in the waste sector

The *climate plan for a green waste sector and circular economy* will implement a tendering model for waste incineration that will make incineration plants compete for waste incineration contracts. Specifically, this means that household waste suitable for incineration will be subject to calls for tender, and the municipalities' 'right to allocate' industrial waste suitable for incineration will be repealed.

The expected effect of having incineration plants compete for waste is that non-competitive and therefore unprofitable plants will be outcompeted. This will increase incentives among plants to ensure efficient incineration in order to be competitive and it will also likely mean that efficient plants will outcompete less efficient plants. On the basis of this, it is assessed that part of the Danish waste incineration capacity will be closed and that total Danish waste incineration capacity will be reduced up to 2035, see the impact assessment for the Waste Incineration Sector Restructuring, etc. Bill.

The Danish Environment Protection Agency projects a drop in volumes of waste suitable for incineration up to 2035 as a result of the *climate plan for a green waste sector and circular economy* and the relevant follow-up agreements from 2022. Waste incineration plants are assumed to fill the remaining capacity through imported waste.

No efficiency improvements or changes in activity level are expected for landfilling, composting, wastewater management or other waste management. Greenhouse gas emissions from these activities are therefore expected to remain relatively constant up to 2035. However, this does not pertain to landfilling, because greenhouse gas emissions from landfills are expected to fall as previously landfilled biological waste degasifies and virtually no more biological waste is added to landfills due to the ban on landfilling waste suitable for incineration.

9.4 Uncertainty and sensitivity analyses

There is considerable uncertainty associated with the projection of greenhouse gas emissions from the waste sector. For example, there is uncertainty about the volume of already landfilled waste and its composition, about the volume of composted garden and parkland waste, about the composition of waste suitable for incineration, as well as about capacity adjustments in response to deregulation.

However, the most significant uncertainty relates to the expected effect of deregulation of the waste incineration sector. To examine the effect of incineration capacity on projection results, CSO23 therefore includes the following three sensitivity analyses:

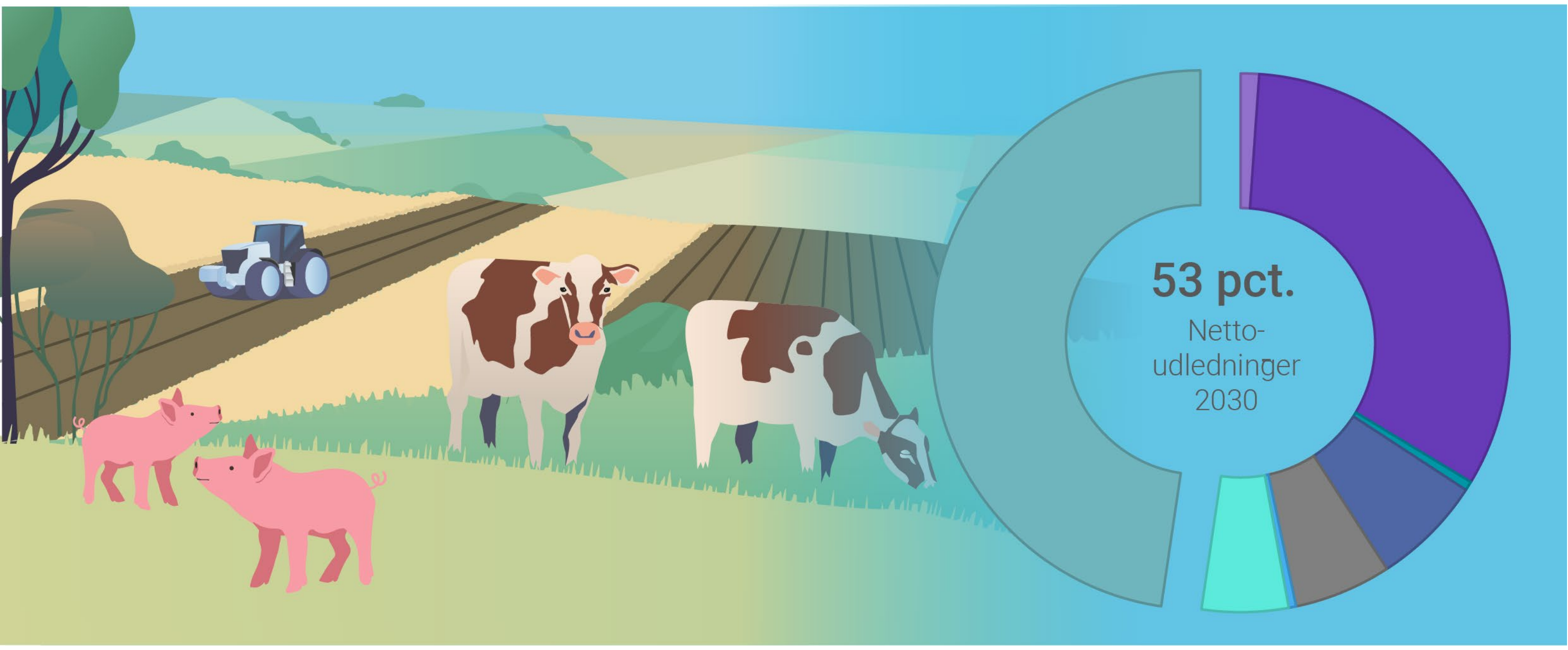
- A scenario with no capacity adjustments
- A scenario with high prices of imported waste
- A scenario with low prices of imported waste and resulting full capacity adjustment.

In the scenario with no capacity adjustments, waste-sector greenhouse gas emissions increase by 0.2 million tonnes CO_2e in 2025, by 1.2 million tonnes CO_2e in 2030 and by 1.5 million tonnes CO_2e in 2035.

In the high-import-price scenario, the sector's CO_2e emissions increase by 0.1 million tonnes CO_2e in 2025, by 0.3 million tonnes CO_2e in 2030 and by 0.4 million tonnes CO_2e in 2035, compared with the CSO23 basic scenario.

In the low-import-price, full-capacity-adjustment scenario, waste-sector greenhouse gas emissions are reduced by 0.5 million tonnes CO_2e in 2025 and by around 0.4 million tonnes CO_2e in 2030, compared with the CSO23 basic scenario. The effect will remain the same in 2035, because the capacity in the basic scenario is expected to be adjusted to Danish waste volumes well before this time.

Note also that a report from the consultancy firm COWI indicates that the volume of composted waste may be considerably lower, and emissions from composting may therefore have been overestimated by more than 0.1 million tonnes CO_2e. It is being considered whether the COWI report should give rise to adjustment of the waste data to achieve a truer estimate of emissions.



10 Agriculture, agricultural land, forests, horticulture and fisheries

This chapter describes expected developments in emissions and removals by:

- agricultural processes
- agricultural land use
- forest land and harvested wood products
- energy consumption in agriculture, horticulture, forestry and fisheries

This sector includes agricultural processes, agricultural land, forests, horticulture and fisheries. In 2021, the transport sector emitted 15.9 million tonnes CO_2e, corresponding to around 34% of total Danish emissions. This means the sector has reduced its emissions by 32% relative to 1990.

In 2025, 2030 and 2035, the sector is expected to emit 17.4, 15.3 and 14.9 million tonnes CO_2e, respectively. In 2035, this will correspond to 58% of total Danish net emissions. This means the sector's total emissions are expected to have been reduced by around 36% in 2035, relative to 1990.

The slightly falling emissions overall up to 2035 are due, in particular, to the following factors:

- A drop in emissions from agricultural processes due to fewer numbers of cattle and pigs and fewer emissions from manure management following from the implementation of new policy measures in the area, for example.
- A drop in emissions from agricultural land due to set-aside and rewetting of carbon-rich agricultural land
- Ongoing energy efficiency improvements of agricultural machinery and the fishing fleet, for example, as well as expected deployment of heat pumps, which will reduce emissions linked to low-temperature processes
- A declining annual forest carbon sink and declining carbon sinks in harvested wood products, due to forest regeneration, for example. The net carbon removals in forests and harvested wood products are expected to approach zero in 2025, and total net emissions by the agriculture and forestry sector will therefore be increased in 2025 relative to 2021.

Greenhouse gas emissions related to energy consumption in the sector are not a part of the sector's reduction target of 55-65% by 2030 compared to 1990, which was decided as part of the *2021 agreement on a green transition of the agricultural sector*. In 2021, the sector's greenhouse gas emissions *excluding emissions related to energy consumption* had been reduced by 30% relative to 1990 and they are expected to have been reduced by 31% in 2030. This leaves an estimated emissions gap of around 24-34 percentage points from the agreement's 2030 target for emissions by the sector.

10.1 Total emissions from the sector

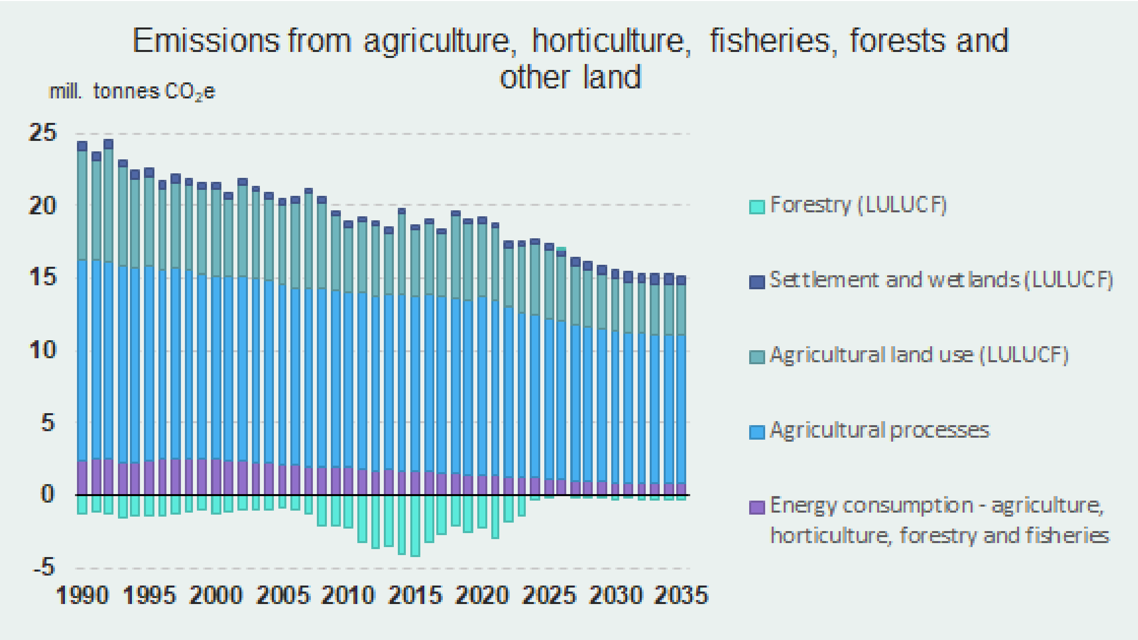
Danish agricultural emissions of greenhouse gases are closely linked to changes in livestock populations, including, in particular, changes in cattle and pig populations, and the breakdown by type of livestock. Similarly, land management by agriculture is decisive, including, in particular, how carbon-rich agricultural land is managed.

The sequestration and storage of carbon in Danish forests and the continued storage of carbon in harvested wood products depend on several parameters. For example, forest carbon sequestration and storage depend on the size of the forest, the number of trees in the forest and their annual sequestration rate, as well as on how much CO_2 is released when trees are harvested or when trees, branches and foliage are left to rot in the forest. The amount of CO_2 stored in harvested wood products depends partly on the number of existing harvested wood products disposed of, and partly on the size of the share of harvested trees used for new wood products.

Energy consumption in agriculture, horticulture, forestry and fisheries accounts for a minor share of the sector's total emissions. Energy consumption is particularly associated with internal transport (including especially operation of agricultural machinery and fishing vessels) and process heat (e.g. for heating hothouses and livestock buildings).

Emissions from the sector include energy-related emissions (CFR-1), as well as agricultural emissions (CFR-3) and LULUCF emissions (CFR-4).

Figure 10.1: Sector emissions for 1990-2035 (million tonnes CO_2e)



Total emissions by the sector for the period 1990-2035 are illustrated in figure 10.1. Emissions are particularly driven by developments in emissions from agricultural processes and agricultural land use. Emissions from agricultural processes are expected to amount to around 69% of total net emissions from the sector in 2035, while the LULUCF[41] and energy consumption by agriculture, horticulture, forestry and fisheries are expected to account for around 24% and 6%, respectively. The remaining emissions will stem from settlements and wetlands, while forests (including harvested wood products) are projected to contribute small net removals.

Emissions by the sector are estimated to be lower in 2021 in CSO23 than in CSO22 primarily due to large net carbon sequestration and storage in forests, while emissions in 2025, 2030 and 2035 are expected to be higher (0.7, 0.2 and 0.4 million tonnes CO_2e, respectively) primarily due to an upwards adjustment of the estimate of emissions from agricultural processes and for LULUCF net emissions by the Danish Centre for Environment and Energy (DCE).

[41] LULUCF stands for Land Use & Land Use Change & Forestry.

The following sections explain the background for developments in the sector's emissions, with special focus on the target years 2025 and 2030 and the projection's final year 2035.

Text box 10.1: Emissions from agricultural processes, agricultural land, forests, horticulture and fisheries broken down by sources

Emissions from agricultural processes:

Agricultural processes cause, in particular, emissions of the greenhouse gases 1) methane (CH_4) from livestock digestion and from manure management, and 2) nitrous oxide (N_2O) from manure management and from cultivation of fields. For a more detailed description of emissions from agricultural processes, see sector memorandum 10B.

Emissions and removals by agricultural land:

Agricultural land includes cropland and grassland in agriculture, where changes in organic carbon pools can result in the removal or emission of CO_2 from/to the atmosphere. These carbon pools include carbon-rich soils, mineral soils and live and dead biomass in fruit trees, berry bushes, shelterbelts and windbreaks. Emissions and removals are calculated as part of LULUCF emissions, which also include emissions from forest land and other land use (settlements and wetlands). Emissions from agricultural land are described in sector memorandum 10C.

Emissions and removals by forest land:

Emissions and removals by forests and harvested wood products are also estimated as part of LULUCF emissions. As forests grow, their standing live biomass sequesters CO_2 from the atmosphere and when agricultural land is afforested more CO_2 is removed from the atmosphere. When forests are felled, this is treated as emissions. If the fellings are not burned but instead used as harvested wood products, for example for building materials, the carbon remains stored in the wood, and this is treated as removals. Emissions and removals by forest land are described in detail in sector memorandum 10D.

Emissions from energy consumption in agriculture, horticulture, forestry and fisheries:

Emissions from energy consumption by the sector are due to the use of fossil fuels, which are used for internal transport and low-temperature process heat, for example. Energy consumption is driven by economic activity in the sector and is also affected by technological developments and continuous energy efficiency improvements. Emissions associated with the sector's consumption of electricity and district heating are included under the electricity and district heating sector in chapter 8. See sector memorandum 10A for a more detailed description of emissions from energy consumption in agriculture, horticulture, forestry and fisheries.

10.2 Agricultural and forestry sector framework conditions, etc.

- Elements from the *agreement on a green transition of the agricultural sector* have been included in CSO23 and were also included in CSO22. These elements concern targeted regulation, set-aside of carbon-rich soils and extensification, for example
- Fewer heads of cattle are expected in CSO23 compared with in CSO22. This change is due to changes to the underlying model, for example
- Expectations concerning set-aside and rewetting of carbon-rich soils in agriculture are the same in CSO23 as in CSO22 and these expectations are based on the subsidies allocated under the *agreement on a green transition of the agricultural sector* and under relevant finance acts
- The method of including projected crop mix and crop yields has been updated and this has resulted in a wider emissions gap than in CSO22
- Expectations about afforestation and other measures to increase net carbon removals in forests are the same in CSO23 as in CSO22 for, and these expectations are based on the funds allocated to afforestation, and similar
- Incentives resulting from the *green tax reform* and the subsidy pool under the *climate agreement on green power and heating* are expected to encourage shifts to heat pumps in heating of livestock sheds in agriculture and greenhouses horticulture
- For fisheries, the re-fuelling abroad by the Danish fishing fleet (cross-border trade effect) has been calculated as a percentage reduction in fuel consumption in the fishing industry. Furthermore, an expected national CO_2e displacement requirement from 2025 is expected to have an effect on internal transport, and CSO23 therefore assumes an increasing incorporation rate of renewable fuels in transport fuel (see sector memorandum 4B for details about biofuel blending in internal transport).

10.3 Emissions from agricultural processes

Agricultural processes include a number of complex organic and chemical processes that cause emissions of methane and nitrous oxide, and, to a lesser extent, CO_2. Emissions from agricultural processes were reduced from 13.9 million tonnes CO_2e in 1990 to 12.1 million tonnes CO_2e in 2021. This trend is expected to continue up to 2030, when emissions are expected to be 10.4 million tonnes CO_2e, corresponding to a reduction of around 25% compared to 1990. The drop in emissions from 2021 to 2030 primarily stems from a drop in emissions from manure management of 1.2 million tonnes CO_2e as a result of new policy measures, for example. Emissions of nitrous oxide from the cultivation of fields are expected to fall by 0.4 million tonnes CO_2e, primarily due to set-aside of agricultural land from 2021 to 2030. Finally, emissions of methane from livestock digestion are expected to fall by 0.3 million tonnes CO_2e from 2021 to 2030, primarily due fewer an expected heads to cattle and pig.

Livestock digestion

Emissions mainly stem from cattle production, in which dairy cattle comprises the largest source. Total emissions from livestock digestion are expected to fall from 4.1 million tonnes CO_2e in 2021 to 3.9 million tonnes CO_2e in 2030. After 2030, emissions are expected to fall additionally by 0.1 million tonnes CO_2e by 2035.

Table 10.1 shows the expected fall in dairy cattle populations and populations of other cattle, including calves, bulls, heifers and suckler cows, up to 2030. The projection is based on the European AGMEMOD model (see memorandum on sector assumptions 10B for details).

Table 10.1: Number of dairy cattle and other cattle, and emissions from their digestion in 2021, 2025, 2030 and 2035

Category of animal	2021	2025	2030	2035
Dairy cattle	564,193	552,510	523,000	494,050
Other cattle	1,108,715	1,077,287	1,039,655	997,321
Enteric emissions from cattle (million tonnes CO_2e)*	3.6	3.4	3.3	3.2

*Cattle account for around 86% of emissions from livestock digestion. Pigs, horses, deer and poultry also emit smaller amounts of methane during digestion.

CSO23 includes a general reduction requirement for livestock digestion following from the *agreement on a green transition of the agricultural sector*. This requirement has been included as a requirement for increased addition of fat to the diet of conventional dairy cattle from 2025 and onwards. In line with other feed materials and feed additives, a higher content of fat in the feed helps to reduce methane emissions. However, the reduction achieved is not enough to offset the increased emissions resulting from efforts by the industry to increase the milk production, such as genetic improvements, increased feed uptake and optimised feed composition.

Manure management

Emissions from manure management were 3.7 million tonnes CO_2e in 2021 and are expected to fall to 2.6 million tonnes CO_2e in 2030. After 2030, emissions are expected to only fall marginally in the absence of new policy measures. Historically, these emissions, which include methane and nitrous oxide from livestock sheds and from storage, have stemmed primarily from Danish pig production.

Table 10.2: Number of piglets and slaughter pigs produced, number of sows, and the emissions linked to managing their manure in 2021, 2025, 2030 and 2035

Category of animal	2021	2025	2030	2035
Sows	1,041,809	959,472	931,209	894,539
Piglets	34,249,801	32,621,758	32,866,845	32,685,062
Slaughter pigs	20,454,275	19,096,629	19,309,604	19,031,039
Manure emissions from pigs (million tonnes CO_2e)*	1.9	1.4	1.3	1.2

*Pigs account for around 54% (2020) and 50% (2030) of emissions from manure management. Cattle account for 44% (2020) and 47% (2030).

In addition to an expected fall in pig production from 2021 up to 2035 (table 10.2), the falling emissions are due to a requirement for more frequent slurry flushing in pig sheds in force from 2023 as a result of the *agreement on a green transition of the agricultural sector*. More frequent slurry flushing leads to a reduction in methane emissions from stables. Furthermore, increased use of environmental technologies in stables has been included in the calculations, along with future significantly increased delivery of pig and cattle slurry for biogas production, and these activities also lead to a reduction of emissions from manure management. Environmental technologies include slurry cooling, acidification in sheds and in the fields, as well as air purification. These technologies affect nitrous oxide and methane emissions from manure management. The projected trend in the use of environmental technologies is based on an assessment carried out by SEGES, see sector memorandum 10B for more details.

Nitrous oxide from cultivation of fields

Nitrous oxide emissions from cultivation of fields come from several emissions sources and depend, in particular, on how much nitrogen is added to the soil. Emissions are expected to fall from 4.3 million tonnes CO_2e in 2021 to 3.9 million tonnes CO_2e in 2030. After 2030, emissions are expected to stabilise at the 2030-level in the absence of new policy measures. The drop from 2021 to 2030 is due to increased expectations about extensification and permanent set-aside of agricultural land as a result of *the agreement on a green transition of the agricultural sector* and implementation of EU's Common Agricultural Policy (CAP) for 2023-2027. These measures lead to lower consumption of artificial fertilisers, which ultimately means reduced nitrous oxide emissions from fields.

Table 10.3: Nitrogen (kt N) and emissions (million tonnes CO_2e) from artificial fertilisers in 2021, 2025, 2030 and 2035

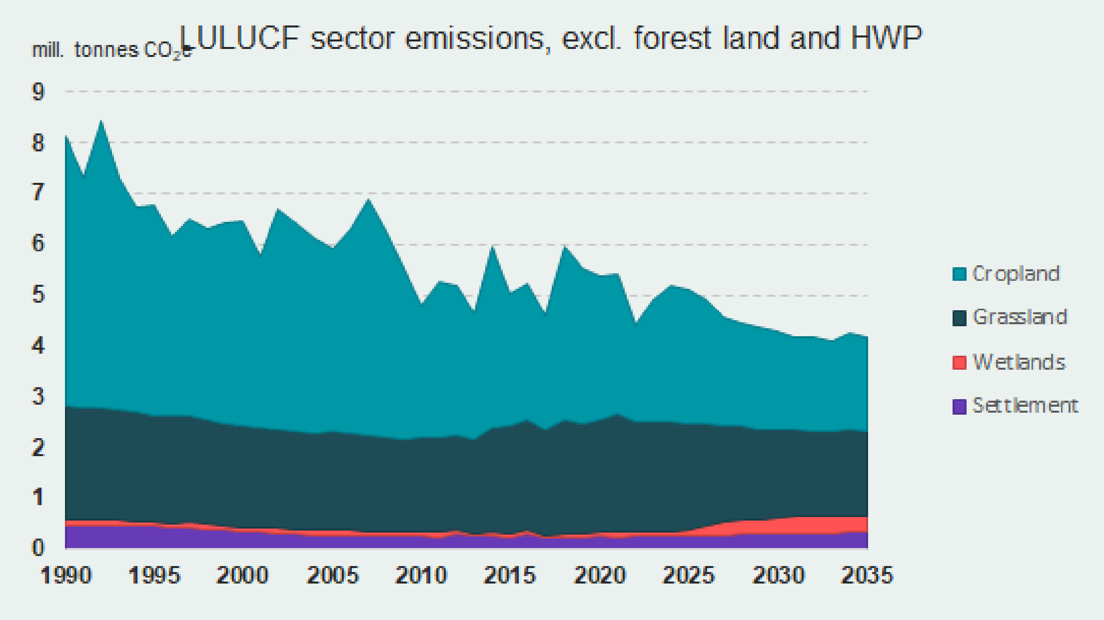
	2021	2025	2030	2035
Nitrogen from artificial fertilisers (kt N)	229	218	214	218
Emissions from artificial fertilisers (million tonnes CO_2e)*	1.0	0.9	0.9	0.9

*Artificial fertilisers account for 24% of nitrous oxide emissions from cultivation of fields in 2021 and 2030.

10.4 Emissions from agricultural land use

Total emissions from agricultural land use fell from 8.1 million tonnes CO_2e in 1990 to 5.4 million tonnes CO_2e in 2021, and they are expected to fall by an additional 1.2 million tonnes CO_2e ending at total emissions of 4.2 million tonnes CO_2e in 2035 (see figure 10.2). From 2021 and onwards, projected reductions are driven by the *agreement on a green transition of the agricultural sector* from 5 October 2021, as well as by Denmark's National CAP Strategic Plan. By far the majority of emissions from land use by agriculture stem from drained, carbon-rich soils which accounted for 5.1 million tonnes CO_2e in 2021, corresponding to around 95% of emissions. The projected reductions in emissions from agricultural land use up to 2035 therefore strongly depend on setting aside of these carbon-rich soils.

Figure 10.2: Emissions from the LULUCF sector exclusive forest land



Source: The Danish Energy Agency (2023a) on the basis of data from the Danish Centre for Environment and Energy (DCE).

Changes since CSO22

Total emissions from land use are expected to be 0.26 million tonnes CO_2e higher in 2025, 0.27 million tonnes CO_2e higher in 2030, and 0.41 million tonnes CO_2e higher in 2035, compared with CSO22. The higher amount of total emissions in CSO23 compared to CSO22 are because the projected crop mix in CSO23 takes account of the area of catch crops, and because of a small drop in the projected increase in yield.

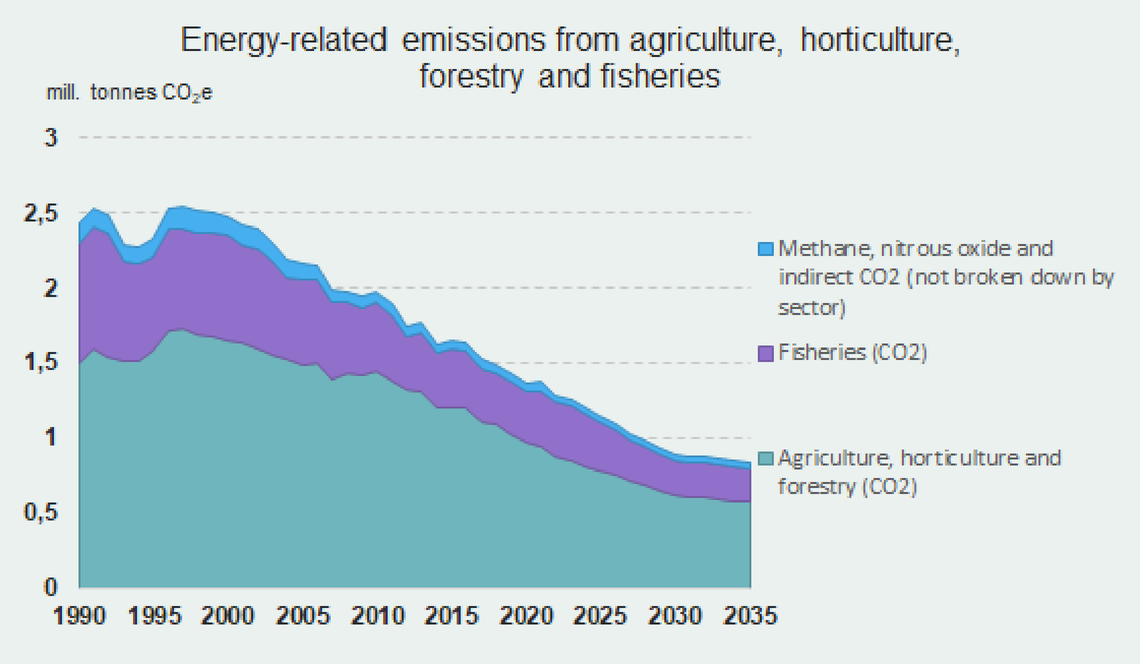
10.5 Emissions and removals by forests and harvested wood products

No new forest projection has been prepared for CSO23. CSO23 therefore uses the same forest projection as CSO22. As illustrated in figure 1, the main results of the forest projection indicate that Danish forests and harvested wood products overall will go from having contributed relatively large annual net removals of greenhouse gases from 1990 up to the present, to contributing significantly smaller annual net removals in the future. There have been average annual net removals of 1.9 million tonnes CO_2e in the period from 1990 to 2021, and in the most recent decade leading up to and including 2021 there were average annual net removals of 3.1 million tonnes CO_2e. Up to 2035, it is expected there will be average annual net removals of 0.4 million tonnes CO2e, and, considered in isolation, there will be small net emissions from forests in the period 2025-2029. The expected low level of removals for the next 15 years is due to past forest development, the current age structure in forests, and expected thinning and felling activities. However, net emissions from forests in 2025 will be offset by slightly higher net removals by carbon sinks in harvested wood products. The forest projection is described in more detail in CSO23 sector memorandum 10D.

10.6 Emissions from energy consumption in agriculture, horticulture, forestry and fisheries

Total energy-related emissions were reduced from 2.4 million tonnes CO_2e in 1990 to 1.4 million tonnes CO_2e in 2021, and these emissions are expected to fall further to 0.8 million tonnes CO_2e in 2035 in the absence of new policy measures (see figure 10.3). The expected level of emissions in 2035 therefore corresponds to a reduction by around 67% relative to the 1990-level.

Figure 10.3: Energy-related emissions 1990-2035 in million tonnes CO_2e (identical to figure 1 in sector memorandum 10A)



For agriculture, forestry and horticulture, energy-related emissions in 2021 stem from the use of gas and diesel oil for internal transport and for low-temperature processes to heat livestock sheds and greenhouses. Up to 2035, emissions from low-temperature processes are expected to fall considerably as a consequence of shifting to heat pumps. Energy-related emissions in agriculture, forestry and horticulture are expected to be 0.62 million tonnes CO_2e in 2030 and 0.57 million tonnes CO_2e in 2035. This corresponds to a reduction of 43% relative to 2020 and 62% relative to 1990. As a result of the deployment of heat pumps, an increasing share of emissions is expected to come from internal transport. In addition to shifting to heat pumps, the reduction in emissions is also expected to be driven by continuous energy efficiency improvements.

For fisheries, emissions in 2021 stemmed exclusively from the use of gas and diesel oil for fishing vessels. From 1990 to 2021, energy-related emissions from fisheries fell from 0.8 million tonnes CO_2e to 0.34 million tonnes CO_2e. Emissions are expected to fall additionally to 0.23 million tonnes CO_2e in 2035, corresponding to a reduction in emissions since 2021 by around 33%. This drop is driven by a continuous adjustment of the fishing fleet towards larger and more energy-efficient vessels as well as to scant penetration of renewables in the fuels used by the fleet.

10.7 Uncertainty and sensitivity analyses

Emissions from agricultural processes

The estimate and projection of emissions from agricultural processes are associated with uncertainty with regard to calculation methods and activity data. The uncertainty is assessed to be significantly higher in the projection than in the estimate of historical emissions, as a number of significant variables are difficult to predict. For example, this pertains to livestock numbers and hectares of crops, which depend on market conditions in the EU and consumer preferences.

An example of an uncertainty with regard to calculation methods is that CSO23 implements standard values from the IPCC's 2019 guidelines instead of using the 2006 guidelines used in previous years' estimates and projections. These changes have led to a total increase in emissions of 0.2-0.6 million tonnes CO_2e compared with CSO22.

The *agreement on a green transition of the agricultural sector* and Denmark's National CAP Strategic Plan have been included in CSO23. As actual implementation of some of these agreements has not yet been finalised, assumptions in future climate projections may have to adjusted. For CSO23, the Danish Centre for Environment and Energy (DCE) has estimated the effect on emissions of introducing a requirement to use Bovaer supplement in feed for conventional dairy cows from 2025 in place of the existing requirement to use supplementary fat. The estimated effect is a reduction in emissions of 0.4 million tonnes CO_2e by 2030, assuming that using Bovaer supplement leads to a 25% reduction in methane emissions per dairy cow. However, more national trials are needed to examine the possible side effects of using Bovaer supplement.

Emissions from agricultural land use

Calculating emissions and removals in the LULUCF sector is generally assessed to be associated with larger uncertainty than for most other sectors in CSO23. This is because net emissions and removals are a result of small, relative changes in very large carbon pools, and a result of biological, non-linear interactions that model best using rather complex models.

There are also uncertainties about the current assumption that soils with 6-12% carbon have emissions corresponding to half that of soils with >12% carbon, which, taken in isolation, in itself could signify that emissions from carbon-rich soils are higher than estimated and, thus, that the effect of setting aside carbon-rich soils could also be higher.

Sensitivity analyses have been performed in connection with the projection of emissions/removals from mineral soils and set-aside of carbon-rich soils in order to assess the difference in results for emissions/removals in a scenario with unchanged set-aside rate for carbon-rich soils and unchanged biomass application to mineral soils.   The set-aside rate for carbon-rich soils assumed in CSO23 is 3 years. If the set-aside rate is changed to 5 years, the result is total added emissions of 0.24 million tonnes CO_2e in 2026, although falling up to 2030. In a scenario with a set-aside rate of 7 years, total emissions will also increase by 0.24 million tonnes CO_2e and will continue to increase up to 2030.

With regard to mineral soils, the sensitivity analyses show that reduced application of biomass will have an effect on carbon sequestration. See CSO23 sector memorandum 10C for a more detailed description of the above.

Emissions and removals by forests

Estimating and projecting emissions and removals by forests and carbon sinks in harvested wood products (HWP) are overall assessed to be associated with a larger methodological degree of uncertainty than most other sectors covered in CSO23. This is because net emissions and removals are a result of small, relative changes in very large carbon pools. It is difficult to predict the annual growth rate and extent of felling in individual years. Developments in annual changes in the forest carbon pool are therefore associated with uncertainty, and changes in felling practices could therefore affect actual developments in future years.

Sensitivity analyses have been performed in the forest projection to assess the difference in results for emissions/removals in forests if other assumptions are made, such as increased annual afforestation, changes in the composition of tree species in connection with afforestation/reafforestation, changes in felling practices, etc.

A) For example, if only quick-growing conifers are planted in new afforestation instead of a mix of coniferous and deciduous species, annual net removals will be increased by 0.3 million tonnes CO_2e by 2035.

B) Similarly, if trees achieve longer live spans, net removals in Danish forests will be higher until the trees are felled or die. In contrast, if a lot of trees are felled in individual years, this will likely lead to significant emissions in these years. A sensitivity analysis shows that net removals by forests could be increased by around 1 million tonnes CO_2e in 2030 if the estimate assumes an increased probability of survival and, thus, longer life spans for trees in various age groups.

Energy consumption in agriculture, horticulture, forestry and fisheries

Despite updates to the assumptions behind the modelling of the economic projection and the projection of energy consumption, there are significant uncertainties linked to modelling these. Furthermore, both agriculture and fisheries operate in international markets and are therefore sensitive to international competition and regulation. For example, there is still uncertainty about the development in fisheries activity due to uncertainty about the allocation of fishing quotas and about the long-term consequences of Brexit for fisheries.

Furthermore, there is also very considerable doubt about when electric motors will be ready to compete in a free market as an alternative to internal combustion engines. Because internal transport is expected to account for by far the largest share of energy-related emissions by 2035, electrification of internal transport could reduce emissions from energy consumption by the sector.

11 Denmark's EU obligations

Denmark has a series of obligations in the EU under the 2030 climate and energy framework. Denmark's obligations include

1. reducing greenhouse gas emissions from the sectors covered by the EU Effort Sharing Regulation (ESR)[42] and from the LULUCF sectors in the period 2021 to 2030. This includes reducing greenhouse gas emissions from agricultural and forest land (LULUCF) and reducing emissions covered by the ESR, such as emissions from agricultural processes, transport, non-energy-intensive industries, waste/wastewater, small district heating and CHP plants, as well as households.

2. meeting a number of obligations concerning use of renewable energy and energy efficiency improvements.[43]

This chapter contains a status of progress with regard to when these obligations will be met under the framework conditions and measures included in CSO23.[44]

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[42] Emissions from sectors under the ESR previously covered non-ETS emissions and were designated as 'non-ETS emissions'. Because the new EU rules entail the establishment of a new emissions trading system for a large part of these emissions, these emissions are now designated as 'emissions under the ESR' / 'ESR emissions'.

[43] See the Renewable Energy Directives and the Energy Efficiency Directive.

[44] See sector memoranda 11a and 11b for a more detailed description.

With regard to Denmark's EU greenhouse gas emission reduction targets, the status is that both ESR and LULUCF emissions will have to be reduced additionally in order to meet the targets.

With regard to the targets related to renewable energy consumption and energy efficiency improvements, the EU's Fit for 55 package proposes significantly tightening the 2030-related targets and obligations for both renewable energy and energy efficiency. At the same time, when adopted, the new, recast energy efficiency directive will impose a series of new binding targets on Member States. It is still too early to determine the extent to which already adopted policies and measures will contribute to the fulfilment of these revised targets and the size of any gap towards meeting these.

11.1 Status of progress towards meeting emissions reduction targets: ESR and LULUCF

Denmark's EU ESR and LULUCF emissions reduction targets have been tightened significantly since CSO22. According to the CSO23 projection, Denmark will not be able to meet these targets without additional reduction measures and/or using flexibility mechanisms.

There is a projected gap towards the ESR target overall for the period 2021-2030 as well as for the LULUCF targets for the period 2026-2029 and for 2030, respectively.

Table 11.1: Expected emissions gaps for Denmark's EU emissions reduction targets

Obligation (emissions reduction target)	Cumulative emissions gap (million tonnes CO_2e)
Effort Sharing Regulation 2021-2030	16
LULUCF 2021-2025	-13
LULUCF 2026-2029	9
LULUCF 2030	2

Note: A negative emissions gap indicates over-achievement of the target.

According to CSO23, Denmark's ESR emissions are expected to have been reduced by around 25 million tonnes CO_2e in 2030, corresponding to a reduction of 38% compared to 2005. This leaves about 12 percentage points to close the gap towards the goal of a 50% reduction by 2030. Including a partial correction for the expected effect of regulation concerning methane leaks from biogas plants and bio-covers, see chapter 2, leads to an overall reduction in emissions by 0.5 million tonnes CO_2e in 2025 and by 0.6 million tonnes CO_2e in 2030. The cumulative emissions gap for the 2021-2030 period therefore comes to around 16 million tonnes CO_2e. This gap can be filled in two ways: 1) through additional national reductions and/or 2) through use of flexibility mechanisms. It is assessed that Denmark will be able to reduce the gap by around 12 million tonnes CO_2e through flexibility mechanisms in the form of annulment of emission allowances and use of LULUCF credits. Furthermore, Denmark also has the option of buying surplus emission allowances from other Member States.

Denmark is expected to over-achieve its LULUCF reduction target for the period 2021 to 2025, whereby Denmark will receive LULUCF credits worth 13 million tonnes CO_2e. With regard to Denmark's LULUCF reduction target for the period 2026 to 2030, it is expected there will be an emissions gap of around 9 million tonnes CO_2e for the period 2026 to 2029 and a gap of around 2 million tonnes CO_2e in 2030. This means that more measures are needed to bridge the gap. The LULUCF emissions gap can be reduced/bridged in several ways. Firstly, Denmark can reduce its LULUCF emissions additionally by adopting new climate measures; for example, this could be as part of meeting the greenhouse gas emission reduction targets in the Danish Climate Act up to 2030. Secondly, Denmark can potentially buy surplus LULUCF credits for the period 2026 to 2030 from other Member States. Thirdly, any surplus emission allowances that Denmark has can be transferred to count towards Denmark's LULUCF target, provided that Denmark reduces its ESR emissions additionally and therefore exceeds its reduction obligation under the ESR.

Note that there is major uncertainty about the calculation and projection of LULUCF-sector emissions and removals, see the description in section 11.3. Furthermore, there is uncertainty about the specific targets because targets are based on future emissions and future reporting of historical emissions, which may be revised retrospectively. Overall, this means that there is large uncertainty about the emissions gap estimate for Denmark's two EU emissions reduction targets.

11.2 Status of progress for renewable energy and energy efficiency

Table 11.2 below describes Denmark's current EU obligations with regard to renewable energy and gives a status report on the prospect of these obligations being met under CSO23.

Table 11.2: Indicators and progress status for Denmark's EU obligations

Indicator	Obligation (emissions reduction target)	Expected progress status	Primary uncertainty
Renewables share (RES)	Ambitious contribution to the common EU renewable energy target of 32% for the EU as a whole[45]	**Met.** The renewables share is projected to be 71% in 2030. This exceeds the 55% that was assessed as *sufficiently ambitious* by the European Commission in connection with NECP reporting in 2020. The implementation track also meets the requirements in the Regulation	Renewables shares in transport (RES-T) and in electricity consumption (RES-E), particularly with regard to the commissioning date for offshore wind and solar PV
Renewables share in transport (RES-T)	At least 14% in 2030[46]	**Met.** RES-T is expected to reach 41% in 2030	Degree of electrification and RES-E
Advanced biofuels in transport	At least 0.2% in 2022, 1.0% in 2025 and 3.5% in 2030 (calculated under the RES-T definition)	The obligation for 2022 is **expected to be met**, whereas the obligations for 2025 and 2030 **are not expected to be met** (see CSO23 sector memorandum 4B). The share of advanced biofuels is projected to reach 0.4% in 2022, 0.5% in 2025 and 0.6-2.0% in 2030	
Renewables share in heating and process energy (RES-H&C)	Annual increase of 1.1 percentage points, except when RES-H&C exceeds 60%	**Met.** In the projection, RES-H&C is expected to exceed 60% from 2022, and an annual rate of increase of more than 1.1 percentage points is expected in most years up to 2030	Developments in district heating and in the deployment of heat pumps in households and industry

Figure 11.1 shows that the total share of renewables (RES) is expected to increase from around 42% in 2020 to 70% in 2030. This does not take account of any statistical transfers between Denmark and other EU Member States.[47] For example, in 2020,

[45] As mentioned in the introduction, with the EU Fit for 55 package, the EU is working to tighten the targets for renewable energy and energy efficiency improvements. In continuation of this, on 30 March 2023, the Council and the European Parliament agreed to raise the 2030 RES reduction target from 32% to 42.5% (with the possibility of further raising the target by 2.5%).
[46] The agreement mentioned above raises the RES-T reduction target from 14% to 29% (also alternative target fulfillment option; but this is not relevant for Denmark).
[47] According to the Renewable Energy Directive, Member States can agree on statistical transfers of renewable energy (RES). The objective of this is to ensure cost-effective collaboration on projects and subsidy schemes and to allow countries which are struggling to meet their targets to buy from countries which have exceeded their targets. Statistical transfers only have significance for RES and therefore have not been included in calculations of other renewables shares according to the Renewable Energy Directive.

Denmark established statistical transfer agreements with the Netherlands, Belgium and Ireland, and this meant that the total Danish renewables share ended at around 32% and not the around 42% mentioned above.

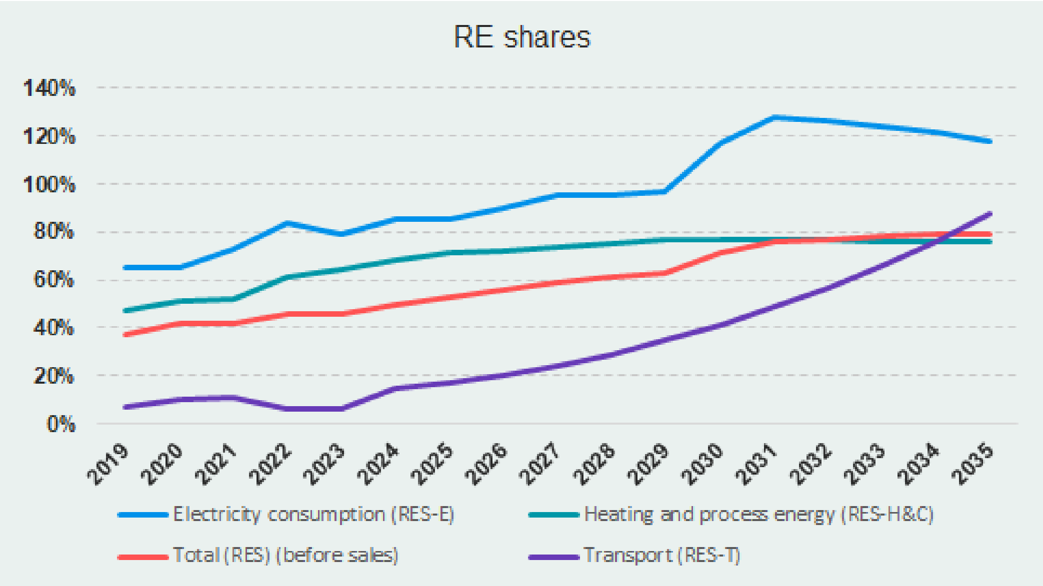
The projection shows that the renewables share in electricity consumption (RES-E) is expected to increase from 65% in 2020 to 117% in 2030 and to peak at 128% in 2031. After this, increasing electricity consumption is expected to exceed the deployment of renewable energy in electricity supply such that the renewables share will drop to 118% up to 2035.[48]

The renewables share in heating and process energy (RES-H&C) will increase from 51% in 2020 to 77% in 2030, after which it evens out at around 76% by 2035. The increase is due in particular to an increasing share of biomethane in mains gas consumption and increased use of heat pumps in households, industry and district heating.

The renewables share in the transport sector (RES-T) is expected to increase from 10% in 2020 to 41% in 2030 due in particular to biofuel blending in diesel and petrol and to electrification of passenger cars and vans and rail transport. After 2030, RES-T is expected to increase further and reach 88% in 2035. Note, however, that the calculation of RES-T includes multipliers on certain types of energy consumption, for example electricity and biofuels. See the annexes in CSO23 sector memorandum 11B for an elaboration on this. Thus, in road transport, which accounts for major share of energy consumption by the transport sector, petrol and diesel is expected to account for around 73% of energy consumption in 2035, while electricity and renewable fuels are expected to account for 19% and 8%, respectively (see CSO23 sector memorandum 4B on consumption and the composition of transport fuels).

[48] See CSO23 sector memorandum 8B on electricity consumption.

Figure 11.1: Renewables shares in total energy consumption, electricity consumption, heating and process energy, and transport, 2019-2035



Note: Renewables shares (RES) have been calculated according to the Renewable Energy Directive/Eurostat. Total RES has been calculated before statistical transfers between Denmark and other EU Member States. After statistical transfers, RES was 31.7% in 2020. The total share of renewables has been adjusted for sales of renewables shares. Because of difficulties in conjunction with transitioning from RED I to RED II, biomass has only been included in official EU estimates in the second half of 2021, and therefore not in the first half of 2021. CSO23 includes the renewable contribution from biomass for all of 2021, as this is deemed to represent the Danish energy system more accurately. This adjustment relative to EU estimates affects the total renewables share, the renewables share in electricity, and the renewables share in heating and cooling. Note also that the calculation of RES-T includes multipliers on certain types of energy consumption, but that these have not been included in the calculation of the total renewables share (RES).

Denmark also has EU energy efficiency targets, and these will soon be broadened with the introduction of the newly recast Energy Efficiency Directive (EED). The primary objective is the EU's overall energy efficiency target, which will be tightened to a goal of consuming at least 11.7% less energy by 2030 compared to the projected energy use for 2030 in the EU Reference Scenario 2020. This translates into a primary energy consumption target of 992.5 million tonnes of oil equivalents (Mtoe) and a final energy consumption target of 763 Mtoe by 2030. All Member States, including Denmark, are obligated to report their indicative national contributions to achieving the overall EU target, and these contributions are determined according to an indicative formula in the EED. The European Commission is expected to update its EU Reference Scenario 2020 by the end of 2023 at the latest. The EED has not yet entered into force, and it is still too early to determine Denmark's indicative contribution and the extent to which Denmark will be able to satisfy this contribution with already adopted policies and measures. This will be dealt with in future Climate Status and Outlook reports.

To support achievement of the EU target, Denmark and other Member States are subject to a number of other obligations under the EED, as well as under the Ecodesign

Directive and the Energy Performance of Buildings Directive (EPBD). The objective of these obligations is to generate energy savings and to increase energy efficiency, and the energy saving obligation under the EED is a particularly important energy efficiency obligation for Denmark. The new, recast EED will increase the energy saving obligation, and Denmark will be obligated to generate more energy savings than under the previous directive. Not all of the energy savings included in CSO23 count towards meeting Denmark's energy saving obligation. This is because special rules apply to how energy savings may be included in meeting the obligation, and Denmark's progress towards meeting the energy saving obligation has therefore been estimated separately. The increased obligation has not yet entered into force, and how to meet it is therefore a subject for future examination.

11.3 Uncertainty and sensitivity analyses

ESR and LULUCF emissions reduction targets

The estimated cumulative emissions gaps for the ESR and LULUCF reduction targets are sensitive to adjustments in annual emissions.

Annual emissions under the ESR are particularly sensitive to livestock populations, the composition of the car fleet (including electric car deployment), as well as the development in the renewables share in mains gas (which affects emissions from households and industry, for example). For example, a previous Climate Status and Outlook report assessed that an increase or decrease of 15% in the population of dairy cattle will increase or reduce annual emissions by about 0.5 million tonnes CO_2e. Note therefore that the separate Emissions Trading System for buildings and transport expected in 2027 has not been included, as it is currently not possible to estimate the effect of this.

With regard to the LULUCF sectors, there is considerable uncertainty as to the size of emissions and removals. This is partly due to large uncertainty linked to estimating and projecting emissions from agricultural and forest land. For example, a sensitivity analysis performed for CSO23 shows that projected net removals by forests could be increased by around 1 million tonnes CO_2e in 2030 if the estimate assumes that the trees in the forest generally reach higher ages before they are felled. On the other hand, emissions from agricultural land can prove to be higher than expected if set-aside and rewetting of carbon-rich agricultural land are delayed.

Finally, there is uncertainty linked to the determination of ESR and LULUCF emissions reduction targets, which will be determined at a later stage and on the basis of updated emissions figures.[49] The EU has also not yet clarified whether negative emissions from subsurface storage of biogenic CO_2 can contribute to target fulfilment.

Renewable energy and energy efficiency targets

Renewables shares in individual years are particularly sensitive to commissioning dates for offshore wind and solar PV. A partial alternative calculation, which includes the North Sea Energy Island and the 4 GW offshore wind under the 2022 *climate agreement on green power and heating*, moreover shows that the renewables share in electricity consumption (RES-E) will increase to 131% in 2030 and further to 162% in 2035 (with unchanged electricity consumption).

As mentioned above, in continuation of the EU Fit for 55 package, the European Commission has proposed tightening the targets for renewable energy and energy efficiency improvements. How the tighter targets will materialise has yet to be decided, and the size of the contribution for the individual Member State has also not been determined.

[49] It is also currently uncertain to what extent the Nord Stream methane gas leak in the Danish Exclusive Economic Zone (EEZ) should be included in the estimate of Denmark's EU ESR obligation.

Appendix 1: Relationship between Denmark's Climate Status and Outlook reports (CSO), Global Reports (GR), scenarios for the Climate Programme (CProg) and analysis assumptions for Energinet (AA)

	Denmark's Climate Status and Outlook reports (CSO)	Denmark's Global Climate Impact Global Report (GR)	Climate Programme (CProg) Scenarios	Analysis assumptions for Energinet (AA)
Background	Part of the annual cycle in the Danish Climate Act (see section 6 of the Climate Act).	Part of the annual cycle in the Danish Climate Act (see section 6 of the Climate Act).	The Climate Programme is included in the annual cycle in the Climate Act (see section 7 of the Climate Act) and the scenarios are prepared for the Climate Programme.	Analysis assumptions (AA) aim to provide a likely development scenario for the Danish electricity and gas system and have been prepared to underpin work by Energinet to plan the developments in the electricity and gas transmission network.

	Denmark's Climate Status and Outlook reports (CSO)	Denmark's Global Climate Impact Global Report (GR)	Climate Programme (CProg) Scenarios	Analysis assumptions for Energinet (AA)
Focus	Calculation of total Danish greenhouse gas emissions in accordance with the UN IPCC methodology (see chapter 3 of the CSO23 memorandum on sector assumptions on principles and policies). In accordance with the UN IPCC methodology, emissions from international shipping and aviation are not included in the projection. The UN IPCC methodology generally entails calculating emissions from the production side (rather than the consumption side).	Describes Denmark's climate impacts outside Danish borders, both positive and negative. Specifically, emissions linked to Danish consumption, imports and exports are calculated. There is also a closer examination of the global climate impacts from Danish cross-border electricity trade, international shipping and aviation, initiatives by the business community, as well as emissions from imports and consumption of soy. Furthermore, the report shows how Denmark is helping to reduce global emissions via a number of authority initiatives.	The scenarios describe different future scenarios for achievement of the 70% target by 2030 and the goal of climate neutrality by 2050. There are four scenarios for achieving climate targets for 2030 and 2050, respectively. The four scenarios are based on different combinations of assumptions about developments in framework conditions (technologies, markets, prices, etc.). The scenarios are not ideals for how achieving climate targets should look, and there are other scenarios for target-attainment than those prepared for the Climate Programme.	Projection of consumption and production of electricity and gas in Denmark.

	Denmark's Climate Status and Outlook reports (CSO)	Denmark's Global Climate Impact Global Report (GR)	Climate Programme (CProg) Scenarios	Analysis assumptions for Energinet (AA)
Time horizon	Historical (from 1990 to 2021 in CSO23) and projected (from 2022 up to 2035 in CSO23).	Historical and current status. Historical data series vary in terms of time covered, depending on the topic, but in some cases, they cover from 1990 to the most recent statistical year (2021 or 2022). GR23 also includes a projection of the effect on foreign emissions up to 2035 based on CSO22, a projection of net imports of different fuels up to 2030 based on CSO22, a projection of the consumption-based climate footprint up to 2035, as well as a projection of the climate footprint of public procurement up to 2030.	Scenarios have been prepared for 2030 and 2050. The scenarios for 2030 should be considered as steppingstones towards the scenarios for 2050.	Up to 2050.
Type of projection	A frozen-policy scenario, i.e. a scenario which assumes no new policy measures are introduced in the climate and energy area other than those decided by the Danish Parliament or the EU before the cut-off date or arising out of binding agreements. The cut-off date for CSO23 is 1 January 2023 (see also chapter 1 of the CSO23 memorandum on sector assumptions on principles and policies.			AA describes an estimate of developments in the parts of the energy area that are relevant for planning by Energinet. AA considers general technological developments and assumes achievement of political targets, also if specific measures to attain these have yet to be adopted. AA is therefore not based on a frozen-policy scenario.

	Denmark's Climate Status and Outlook reports (CSO)	Denmark's Global Climate Impact Global Report (GR)	Climate Programme (CProg) Scenarios	Analysis assumptions for Energinet (AA)
Application	Examines to what extent Denmark's climate and energy targets and commitments will be met within the framework of current regulation.	Calculates how Danish consumers, businesses and authorities influence global emissions positively or negatively.	The scenarios are prepared as technical background material for the climate programme and are also reproduced in the actual Climate Programme. The scenarios can be applied as a technical basis for considerations regarding achievement of the 70% target in 2030 and the zero-emissions target for 2050.	AA is used by Energinet to plan developments in the Danish electricity and gas transmission network.
Further information	https://ens.dk/service/fremskrivninger-analyser-modeller/klimastatus-og-fremskrivning-20233	https://ens.dk/service/fremskrivninger-analyser-modeller/global-afrapportering-2022	https://ens.dk/service/fremskrivninger-analyser-modeller/tekniske-analyser-til-baggrund-klimaprogram-2022 https://kefm.dk/aktuelt/nyheder/2022/sep/nyt-klimaprogram-danmark-er-knap-trefjerdedele-af-vejen-til-klimamaalet-	https://ens.dk/service/fremskrivninger-analyser-modeller/analyseforudsaetninger-til-energinet

Appendix 2: List of CSO23 sector memoranda and memoranda on sector assumptions

In addition to the main report, CSO23 comprises 18 sector memoranda and 10 memoranda on sector assumptions. All of these memoranda are shown in the tables below.

Table A1.1: CSO23 sector memoranda

	Sector memorandum
3A	Households
4A	Transport
4B	Consumption and composition of transport fuels
5A	Service sector
6A	Manufacturing industries and building and construction
7A	Extraction of oil and gas as well as refineries
7B	Biogas, PtX and renewable fuels
7C	Consumption and composition of mains gas
8A	Electricity and district heating (excluding waste incineration)
8B	Electricity demand
9A	Waste incineration
9B	Other waste and wastewater
10A	Energy consumption in agriculture, horticulture, forestry and fisheries
10B	Agricultural processes
10C	Agricultural land
10D	Forest land and harvested wood products
11A	Denmark's greenhouse gas emission obligations in the EU
11B	Denmark's EU obligations towards renewable energy and selected national agreements

Table A1.2: CSO23 memoranda on sector assumptions and memoranda on assumptions

Memorandum on sector assumptions	Chapter no.	Chapter
Introduction to CSO23 assumptions material		
Principles and policies	Chapter 1	Frozen-policy principles
	Chapter 2	Policies and agreements included in CSO23
	Chapter 3	Emission inventory principles
Prices and growth	Chapter 1	Fuel prices
	Chapter 2	CO_2 allowance price
	Chapter 3	Assumptions about economic growth

Memorandum on sector assumptions	Chapter no.	Chapter
Transport	Chapter 1	FREM transport model
	Chapter 2	Models and methodology for road transport
	Chapter 3	Road transport assumptions
	Chapter 4	Rail transport – Methodology and assumptions
	Chapter 5	Domestic shipping – Methodology and assumptions
	Chapter 6	Domestic aviation – Methodology and assumptions
	Chapter 7	Other transport – Methodology and assumptions
Energy consumption and process emissions by households and the corporate sector	Chapter 1	IntERACT model
	Chapter 2	Individual heating by households
	Chapter 3	Household use of appliances
	Chapter 4	Data centres
	Chapter 5	Cement production
	Chapter 6	Energy consumption in agriculture, horticulture, forestry and fisheries
	Chapter 7	F gases
Production of oil, gas and renewable fuels	Chapter 1	Oil-gas production
	Chapter 2	Refineries
	Chapter 3	Biogas production
	Chapter 4	Power-to-X
Electricity and district heating	Chapter 1	RAMSES model
	Chapter 2	DH-Invest model
	Chapter 3	Foreign electricity production capacities, etc.
	Chapter 4	Danish interconnectors
	Chapter 5	Offshore wind
	Chapter 6	Onshore wind
	Chapter 7	Solar PV
	Chapter 8	Thermal production capacity (excl. waste incineration)
Memorandum on assumptions		Waste incineration
Memorandum on assumptions		Other waste
Memorandum on assumptions		CCS
Agricultural processes, agricultural land and forests	Chapter 1	Agricultural processes
	Chapter 2	Agricultural land and other land
	Chapter 3	Forest land and harvested wood products
	Chapter 4	Danish Centre for Environment and Energy's (DCE) calculation methods for agriculture and LULUCF

Appendix 3: List of CSO23 datasheets

A number of data sheets are published in the context of CSO23. The data sheets are listed in the table below.

Table A2.1: CSO23 datasheets

File name (in Danish)	Description
CSO23 results - Numbers behind the figures	• Includes the data behind figures in the CSO23 main report and sector memoranda
CSO23 assumptions - numbers behind the figures	• Includes the data behind figures in CSO23 memoranda on assumptions
CSO23 Common Reporting Format (CRF) table	• Emission inventories per greenhouse gas type for the years 1990-2035. Statistical years are observed years, while the projection period uses normal years. • CSO23 uses Danish Energy Agency historical emissions data. Totals are identical with Danish Centre for Environment and Energy (DCE) emissions data, but there are slight differences in how emissions break down between certain categories. • CSO23 has been calculated using the new global warming potential factors from the IPCC's 5th Assessment Report (AR5).
CSO23 CRF tables broken down by ETS and ESR emissions	• Emission inventories by ETS (ETS) and non-ETS (ESR) emissions for the years 1990-2035. Statistical years are observed years, while the projection period uses normal years. • CSO23 has been calculated using the new global warming potential factors from the IPCC's 5th Assessment Report (AR5).
Energy balance	• National energy balance for fuels for the years 2015-2035
Sector data sheets	• Electricity and district heating • Electricity system hourly series • Transport • Agriculture • LULUCF.

Appendix 4: The relationship between CSO23 sectors and CSO22 sectors and CRF table

The relationship between CSO23 sectors and CSO22 sectors

As in CSO22, in CSO23, emissions are broken down by eight sectors and CCS. The only change in the sectoral division in CSO23 relative to CSO22 is that emissions linked to methane leaks from biogas plants are excluded.

Table A3.1: CSO23 sectors

CSO23 sector	Remarks
Households	Excluding energy consumption and emissions arising from transport, including the sector's share of F-gas emissions
Transport	Including the sector’s share of F-gas emissions
Service sector	Including data centres and the sector’s share of F-gas emissions
Manufacturing industries and building and construction	Including the sector’s share of F-gas emissions
Production of oil, gas and renewable fuels	Including methane leaks from biogas production
Electricity and district heating	Excluding emissions from waste incineration
Waste and wastewater	Including emissions from waste incineration, landfills, wastewater and composting, and excluding leaks from biogas plants.
Agriculture, agricultural land, forests, horticulture and fisheries	Including energy consumption by the sector

Note: Because CCS has not been broken down by sector in CSO23, the technology is instead dealt with as a separate source of negative emissions.

The relationship between CSO23 sectors and CRF tables

The sectoral division in CSO23 follows the categories in the CRF tables as far as possible. The table below shows how the greenhouse gases CO_2, CH_4, N_2O, and indirect CO_2 under the various CRF categories break down by CSO23 sectors (here identified by chapter numbers in the main report). F gases are broken down by sector on the basis of the distribution key in CSO23 memorandum on assumptions 9C.

Table A4.1: The relationship between CRF categories and CSO23 sectors

CRF code	Description	CO_2, CH_4, N_2O, Indirect CO_2
1A1a	Public electricity and heat production	08
1A1ax	Public electricity and heat production (Waste incineration)	09
1A1b	Petroleum refining	07
1A1c	Other energy industries (oil/gas extraction)	07
1A2	Combustion in manufacturing industry	06
1A2gvii	Industry - Other (mobile)	06
1A3a	Domestic aviation	04
1A3bi	Road transport - Cars	04
1A3bii	Road transport - Light duty trucks	04
1A3biiix	Road transport - Heavy duty trucks	04
1A3biiiy	Road transport - Busses	04
1A3biv	Road transport - Motorcycles and mopeds	04
1A3bx	Road transport - Border trade	04
1A3c	Railways	04
1A3d	Domestic navigation	04
1A4ai	Commercial and institutional	05
1A4aii	Commercial and institutional (mobile)	05
1A4bi	Residential	03
1A4bii	Residential (mobile)	03
1A4ci	Agriculture, forestry and aquaculture	10
1A4cii	Ag/for./fish. (mobile)	10
1A5bi	Military (mobile)	04
1A5bii	Recreational boats (mobile)	04
1B2a	Fugitive emissions from oil	07
1B2b	Fugitive emissions from gas	07
1B2c	Fugitive emissions from flaring	07
2A0	Mineral industry - excl. cement production	06
2A1	Mineral industry - cement production	06
2B	Chemical industry	06
2C	Metal industry	06
2D	Non-energy products from fuels and solvent use	06
2E	Electronic industry	06
2F	Product uses as ODS substitutes	06
2G	Other product manufacture and use	06
2H	Other industrial processes	06
3A	Enteric fermentation	10
3B	Manure management	10
3D	Agricultural soils	10
3F	Field burning of agricultural residues	10
3G	Liming	10
3H	Urea application	10

CRF code	Description	CO_2, CH_4, N_2O, Indirect CO_2
3I	Other carbon-containing fertilizers	10
4A	Forest land	10
4B	Cropland	10
4C	Grassland	10
4D	Wetlands	10
4E	Settlements	10
4F	Other Land	10
4G	Harvested wood products	10
4H	Other LULUCF	10
5A	Solid waste disposal	09
5B1	Composting	09
5B2	Anaerobic digestion at biogas facilities	07
5C	Incineration and open burning of waste	09
5D1a	Emission, anaer. treat. Plants/Venting	07
5D1b	Wastewater treatment and discharge - other	09
5E	Other waste	09

Note: *03 is households; 04 transport; 05 service sector; 06 manufacturing industries and building and construction; 07 production of oil, gas and renewable fuels; 08 electricity and district heating; 09 waste; 10 agriculture, agricultural land, forestry, horticulture and fisheries.* CH_4 *is methane and* N_20 *is nitrous oxide.*

Appendix 5: Calculation of CSO23 net emissions including corrections on the basis of CSO23 CRF calculations

Table A5.1: Relationship between CSO23 net emissions including corrections and CSO23 CRF calculations

Million tonnes CO_2e	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
CSO23 net emissions in the CRF estimate	46.3	46.5	42.8	44.0	40.2	37.9	35.8	34.3	30.9	29.5	28.7	28.0	27.8	27.2	26.3
Partial correction for methane leaks from biogas	0.0	0.0	0.0	-0.4	-0.5	-0.5	-0.5	-0.5	-0.5	-0.6	-0.6	-0.5	-0.5	-0.5	-0.5
Partial correction for bio-covers at landfills	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CSO23 total net emissions including partial corrections	**46.2**	**46.5**	**42.8**	**43.6**	**39.7**	**37.4**	**35.3**	**33.8**	**30.3**	**28.9**	**28.1**	**27.5**	**27.2**	**26.7**	**25.8**

Appendix 6: Total biogenic energy-related CO_2 emissions in CSO23

The calculation of sector emissions follows the UN IPCC methodology, because the Climate Act stipulates that the calculation of Danish emissions relative to the 70% target has to follow the UN IPCC methodology. CO_2 emissions from consumption of biomass are included in the LULUCF sector in the country in which the biomass is harvested. When Danish and imported biomass and biofuels are burned for energy purposes, the resulting biogenic CO_2 emissions are not therefore included in order to avoid double counting (see chapter 3 "Emission inventory principles" in the CSO23 memorandum on sector assumptions on principles and policies). Pursuant to the UN IPCC methodology, CO_2 emissions from consumption of biomass for energy should, however, be calculated and reported under a so-called 'memo item'. This appendix shows the total biogenic energy-related CO_2 emissions from burning biomass and biofuels.

As can be seen from figure App.6.1, total biogenic energy-related CO_2 emissions followed an upward trend from 1990 to 2021, when they totalled 20.1 million tonnes CO_2. Up to 2025, biogenic energy-related CO_2 emissions are estimated to make up around 22 million tonnes CO_2, except for in 2023 when they are expected to be at 20.3 million tonnes CO_2. The fluctuations in this period stem mainly from the electricity and district heating sector and should be considered in the context of trends in relative fuel prices, which are of significance for the fuel mix in the electricity and district heating sector (see also CSO23 sector memorandum 8A). The electricity and district heating sector generally accounts for the largest share of total biogenic energy-related CO_2 emissions in the projection period, although the electricity and district heating sector's share of total biogenic energy-related CO_2 emissions is projected to fall from 60% in 2025 to 45% in 2030.

Figure A6.1: Total biogenic energy-related CO_2 emissions by sector

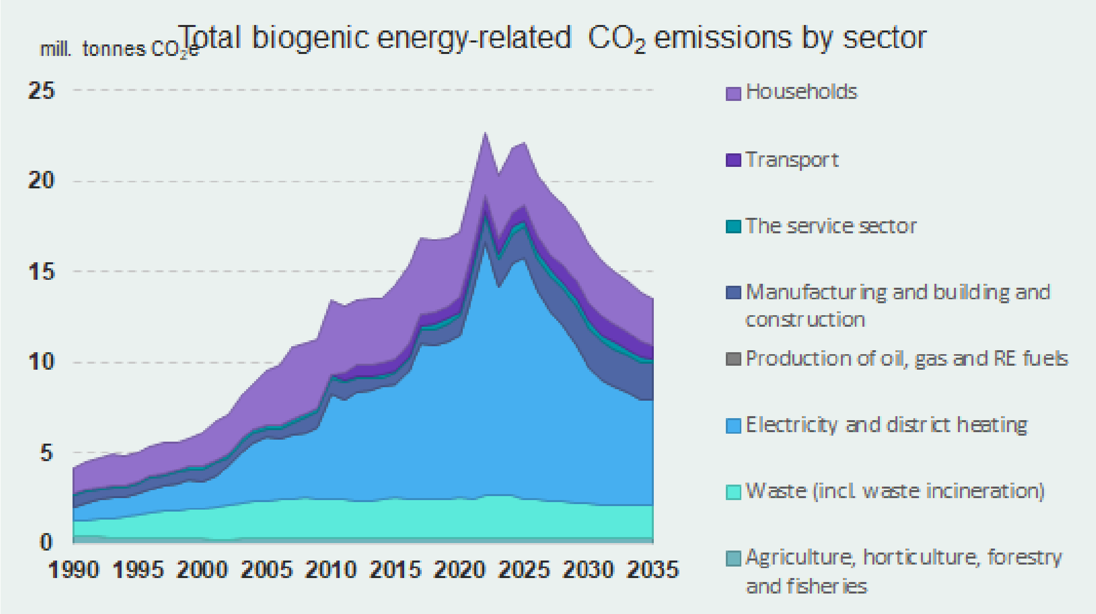
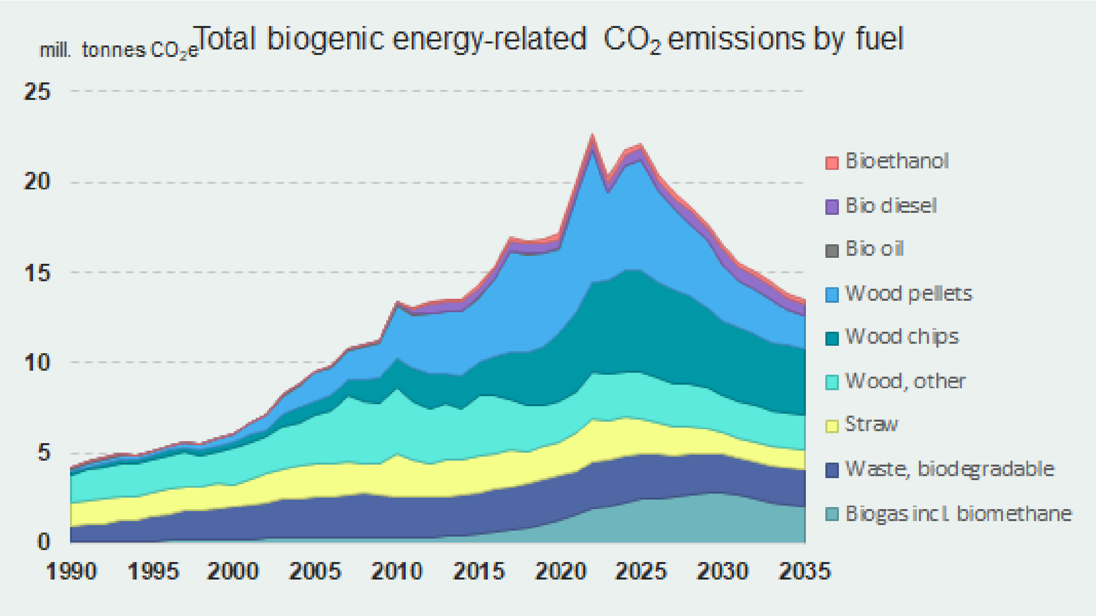


Figure App.6.2 shows trends in and the composition of biogenic energy-related CO_2 emissions by fuel. As illustrated by the figure, most of the biogenic energy-related CO_2 emissions stem from wood in the form of wood chips, wood pellets and other timber. The biogenic energy-related CO_2 emissions from biomethane will also increase in line with the increased production of biomethane and thereby increasing proportion of renewable energy in mains gas.

Figure A6.2: Total biogenic energy-related CO_2 emissions by fuel



Appendix 7: Glossary and abbreviations

Glossary

Biofuels: Biofuels produced from biological materials. A distinction is made between first- and second-generation biofuels. First generation biofuels are primarily ethanol and biodiesel produced on the basis of food crops. Bioethanol is typically produced from crops containing starches and sugar, such as cereal and sugar cane, while biodiesel is typically produced from oil crops, such as rape, soybean and palm. Second generation biofuels are typically produced from residual products from agriculture and industry.

Biogenic energy-related CO_2 emissions: CO_2 emissions arising from burning biomass.

Biomass: An umbrella term for all organic material that is the product of photosynthesis in plants driven by solar energy. The most common products in an energy context are straw, firewood, wood chips, wood pellets, wood waste, biodegradable waste, etc.

Biomethane: Biogas that has been upgraded to meet the supply requirements for gas in the mains gas grid.

CO_2 intensity: A measure of the amount of CO_2 emissions relative to economic production. Is calculated as the ratio between CO_2 emissions and production value.

Common Reporting Format (CRF): Standard format for reporting emission inventories in accordance with the UN IPCC methodology for calculating emissions.

Greenhouse gas emissions: Greenhouse gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and fluorinated greenhouse gases (F gases). The gases have different greenhouse effects but are converted into **CO_2 equivalents** (abbreviated CO_2e) based on their Global Warming Potential (GWP) over a 100-year time period relative to CO_2. CO_2e emissions are therefore a way in which to estimate greenhouse gas emissions that allows for adding up different greenhouse gases with different impacts on the greenhouse effect with regard to the potency of the gas and the time it is in the atmosphere. With the CO_2e unit, the climate impact of the individual gas is converted to the corresponding impact in units of CO_2.

Energy intensity: A measure of energy consumption relative to economic production. Is calculated as the ratio between energy consumption and production value.

Final energy consumption: Final energy consumption is energy consumption delivered to end users, i.e. private and public-sector businesses as well as households. Uses include manufacture of goods and services, space heating, lighting and other appliance consumption as well as transport. Added to this is oil consumption for non-energy purposes, i.e. lubrication and cleaning as well as bitumen for paving surfaces. Energy consumption in connection with extraction of energy, refining and conversion is not included in final energy consumption. The definition and breakdown of final energy consumption follow the International Energy Agency's (IEA's) and Eurostat's guidelines. Energy consumption for transport by road and railway, by sea, by air, and by pipeline - irrespective of consumer - is subsequently taken out of the total final energy consumption figure as an independent main category. This means that energy consumption by businesses and households is calculated exclusive of consumption for transport purposes. Moreover, final energy consumption excludes cross-border trade in oil products, defined as the quantity of petrol, gas/diesel fuel and pet coke purchased by private individuals and transport operators etc. on one side of the border and consumed on the other side of the border.

Observed (actual) energy consumption: Observed energy consumption is found by adding distribution losses and energy consumption in connection with energy extraction and refining to final energy consumption. To this figure is added own consumption of energy in connection with production of electricity and district heating.

Greenhouse gas emissions NOT covered by the EU ETS system (non-ETS): Non-ETS emissions primarily stem from transport, agriculture, households, other industries, waste, and a number of small-scale CHP plants, i.e. numerous large and small emissions sources. Regulation takes place through national measures by the individual countries which have EU-determined greenhouse gas emission reduction targets relative to 2005 levels. The baseline year is 2005, as this year was the earliest year with data that made it possible to distinguish between ETS and non-ETS emissions.

iLUC impact: When biomass for use as biofuels is grown in an area that was previously used for food production, then this food production will be transferred to new land because the demand for food products is assumed to be unchanged. iLUC emissions are emissions that occur when previously unfarmed land is converted to agricultural land to produce food crops as the indirect result of the use of biofuels.

Indirect emissions: Indirect CO_2 is calculated on the basis of emissions of CH_4, NMVOC and CO, which oxidize to CO_2 in the atmosphere. Only fossil emissions of CH_4, NMVOC and CO are included in the calculation.

Carbon pool: Forests and other land (primarily cropland and grassland in agriculture) is an important carbon pool, as CO_2 can be either stored in or released from trees, plants and soils. The size of the carbon pool in forests and other land depends on how the land and the forests are used.

Greenhouse gas emissions covered by the EU ETS system (ETS): ETS emissions include emissions from energy production, heavy industry, aviation and other large point sources. The total number of emission allowances is set at EU level and this number is tightened annually. The allowances are traded on a common European market where ETS companies trade allowances and where some types of production are allocated free allowances.

Mains gas: In Denmark, fossil natural gas is mixed with biomethane (i.e. upgraded biogas) in the mains gas grid. Consumers do not have the option of choosing which type of gas is used, as fossil natural gas and biomethane are mixed together in the gas grid and become mains gas.

LULUCF: Inventory of carbon removals and emissions linked primarily to soil cultivation and forestry activities.

Traffic: Number of kilometres travelled by a vehicle in one year.

RE (renewable energy): Defined as solar energy, wind power, hydropower, geothermal energy, ambient heat for heat pumps and bioenergy (straw, wood chips, firewood, wood pellets, wood waste, **bioliquids, biomethane, biodegradable waste and biogas).**

Renewables shares: For a summary of the principles for determining renewables shares, see the Annex to sector memorandum 11B.

Renewable fuels: Fuel produced on the basis of renewable energy sources. In CSO23, this is an overall term for biomass-based fuels (e.g., bioethanol and biodiesel) and fuel produced using electrolysis (PtX technology).

Abbreviations

DECO20: Denmark's Energy and Climate Outlook 2020

CO_2e.: CO_2 equivalents

CRF: *Common Reporting Format*

DCE: Danish Centre for Environment and Energy, Aarhus University

ETS: The European Emission Trading System

ESR: *The EU's Effort Sharing Regulation.*

iLUC: *Indirect Land Use Change*

CSO21: Denmark's Climate Status and Outlook 2021

CSO22: Denmark's Climate Status and Outlook 2022

LULUCF: Land Use & Land Use Change & Forestry

NECP: National Energy and Climate Plan

PJ: Peta Joule (1 PJ = 1000 TJ = 1 million GJ = 1 billion MJ)

PtX: Power-to-X

RES: Renewable energy share (total renewables share)

RES-E: Renewable energy share - electricity (renewables share in electricity)

RES-H&C: Renewable energy share - heating and cooling (renewables share in heating and process energy)

RES-T: Renewable energy share - transportation (renewables share in transport)

TWh: Tera Watt hours (1 TWh = 1000 GWh = 1 million MWh = 1 billion kWh)

RE: Renewable energy

Appendix 8: References

Each CSO23 sector memorandum contains a list of references for the memorandum in question. This appendix covers only references relevant for the main report and which are not part of the CSO23 material. See Appendix 1 for a list of CSO23 sector memoranda and memoranda on assumptions.

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  and:

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