Denmark's Climate Status and Outlook

2022

Danish Energy Agency

Denmark's Climate Status and Outlook 2022

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Danish Energy Agency, Carsten Niebuhrs Gade 43, DK-1577 Copenhagen V
Tel: +45 33 92 67 00, E-mail: ens@ens.dk

Internet: http://www.ens.d

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1 About Denmark's Climate Status and Outlook 2022

Denmark's Climate Status and Outlook 2022 (CSO22) is an account of how Danish greenhouse gas emissions have developed from 1990 to 2020, as well as a technical, expert assessment of how greenhouse gas emissions as well as energy consumption and production will evolve over the period up to 2035 based on a frozen-policy scenario.

A 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 2022, 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.

CSO22 thus serves to examine to what extent Denmark's climate and energy targets and commitments will be met within the framework of current regulation. CSO22 can thus be used as a technical reference when planning new measures in the climate and energy area, and when assessing the impact of such measures.

1.1 What is the basis for CSO22?

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% in 2025 and 70% in 2030 relative to the 1990 level. The Climate Act also sets out an annual cycle to ensure annual follow-up on whether climate efforts are supporting the fulfilment of targets in the Climate Act. According to the annual cycle, every year in April, Denmark's Climate Status and Outlook report is to review Denmark's progress towards meeting its climate targets.

1.2 What does CSO22 include and how are climate projections made?

To understand the results in CSO22, it is important to know what emissions are covered in the climate projections, what policy measures, etc. are included and how the projections are made.

[1]The Climate Act also requires global reporting on the international impacts of Danish climate efforts. The annual global reporting for 2022 has been prepared and published as a separate publication in parallel with CSO22. References to CSO22 therefore only pertain to Denmark's national climate status and outlook.

What emissions are included in CSO22?

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 Climate Act's targets 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 CSO22?

The cut-off date for including policy measures in CSO22's modelling for the period 2021 to 2035 has been defined as 1 January 2022. The cut-off date for including policy measures in CSO21 was 1 January 2021. The new policy measures included in CSO22 are the agreement on a green transition of the agricultural sector, the "Denmark Forward" 2035 infrastructure plan agreement, the green transport pool realisation agreement, and the agreement on regulation of the EV charging market, as well as an additional 2GW offshore wind deployment and a technology-neutral tendering procedure for negative emissions (agreed as part of the 2022 Finance Act), and more. For a full list of the new policy measures included in CSO22, as well as a list of the measures that have not been included, either because they have yet to be sufficiently concretised or because it is (currently) not possible to estimate their impact, see the underlying CSO22 memorandum on assumptions 2A.

Note that the energy islands decided as part of the 2020 climate agreement for energy and industry, etc. have not been included in the CSO22 basic scenario, because establishment of these islands depends on measures that have yet to be decided, for example measures concerning interconnectors.[3] The agreement on a tendering procedure to promote hydrogen and green fuels (Power-to-X) from 15 March 2022 has also not been included in CSO22. This is because the agreement was concluded after the cut-off date for inclusion of measures in the projections.

In addition to policy measures, CSO22 includes an updated overall assessment of developments based on current market conditions. Amongst other things, this includes actual investment decisions by various players.[4] Note that the assumptions behind CSO22, including assumptions about fuel prices and the CO_2 allowance price, have been established as at the end of 2021, and that CSO22 therefore does not take

[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 the underlying CSO22 memorandum on assumptions 2B for further explanation of the emissions covered in CSO22.

[3] See the underlying CSO22 memorandum on assumptions 2C for further explanation of the principles behind the frozen-policy approach in Denmark's Climate Status and Outlook reports.

[4] For a description of how CSO22 deals with collaboration agreements between the government and businesses, see the underlying CSO22 memorandum on assumptions 2C.

account of the subsequent developments in Ukraine and any derived effects on energy markets, etc.

How was CSO22 prepared?
CSO22 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 CSO22 was prepared is described in more detail in the underlying CSO22 memorandum on assumptions 0, and the specific assumptions, data and models used in the projection of emissions, etc. are described in several other underlying memoranda on assumptions, see Appendix 2.

1.3 What uncertainty is linked to CSO22?

It is important to bear in mind that sensitive assumptions and uncertainties affect the key results in CSO22. 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 behaviour and technologies, external factors such 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 CSO22 material structured?

CSO22 consists of a main report, underlying sector memoranda and memoranda of 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 assumptions. These memoranda were subject to public consultation in January 2022. For a list of all written CSO22 material, see Appendix 2.

In addition to the main report and the sector memoranda, CSO22 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.[5] See Appendix 3 for further information on this CSO22 data and a list of CSO22 data sheets.

[5] 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 2020, total greenhouse gas emissions, including carbon removals and emissions by soils and forests, came to 44.9 million tonnes CO_2e. This means that, in 2020, Danish greenhouse gas emissions had been cut by 43% compared to total Danish emissions in 1990. Note that the Covid-19 pandemic had an effect on activity levels in some sectors in 2020, and that the pandemic therefore also put its mark on energy consumption and greenhouse gas emissions in these sectors. Although 2020 is the most recent statistical year, analyses in CSO22 sometimes use emissions in 2019, in which activity levels must be assumed to represent a fairer basis.

Denmark's climate outlook: based on current adopted policies, total net emissions[6] are expected to have fallen to 41.4 million tonnes CO_2e in 2025 and 33.6 million tonnes CO_2e in 2030, corresponding to a reduction of 47% in 2025 and 57% in 2030 compared to the 1990 level. Thus, as things stand, projections reveal an estimated emissions gap of 3-7 percentage points in 2025 and 13 percentage points in 2030 compared with the reduction targets set out for 2025 and 2030 in the Climate Act. This corresponds to a shortfall of 2.4-5.5 million tonnes CO_2e in 2025 and 10.1 million tonnes CO_2e in 2030. In 2035, total net emissions are expected to have been reduced additionally to 30.2 million tonnes CO_2e.

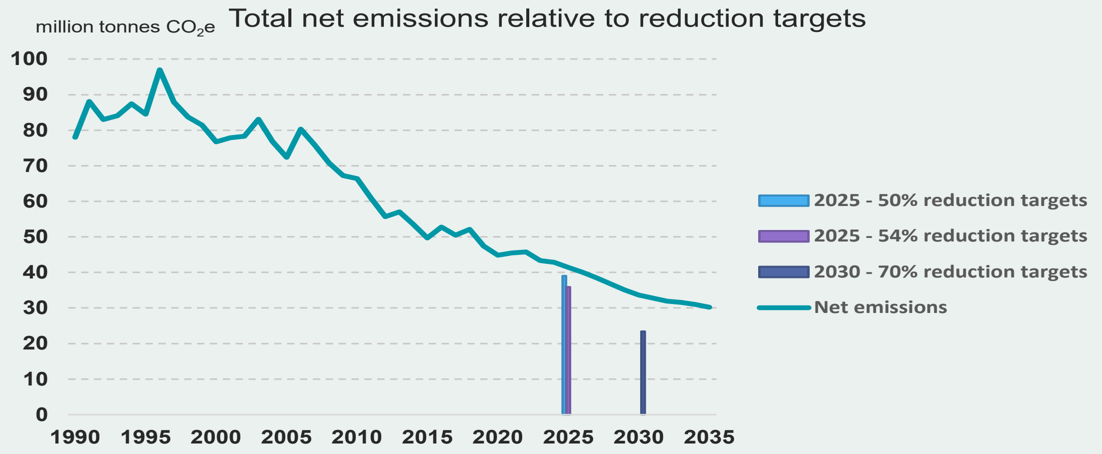
Naturally, the projections in Denmark's Climate Status and Outlook reports are linked to uncertainty, and this year's uncertainty is particularly pronounced. This greater general uncertainty is due partly to uncertainty as to the effects of the Covid-19

[6]The concept of "total net emissions" refers to total emissions (including LULUCF), and after inclusion of CCS.

pandemic and partly the effects of the current uncertainties in the energy markets following from the situation in Ukraine, which, as already mentioned, have not been included in CSO22. These mentioned circumstances could lead to permanent structural changes and permanent changes in consumer behaviour and choice of technology, which are not reflected in this year's projection. This year's projection should therefore be interpreted in light of this.

The expected 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 2025 and 2030 reduction targets



Note: The extra partial effect of higher allowance prices on emissions from refineries of around 0.08 million tonnes CO2, which has been deducted from the emissions gap for 2030 (cf. table 2.1) is not reflected in emissions estimates in this figure.

2.1 Status of progress towards reduction targets set out in the Climate Act[7]

Projected total emissions in 2025 and 2030 will be 41.4 million tonnes CO_2e and 33.6 million tonnes CO_2e, respectively, if no new measures are introduced in the climate and energy area after 1 January 2022; the cut-off date for including policy measures in CSO22. This leaves an emissions gap of 2.4-5.5 million tonnes CO_2e compared with the Climate Act's indicative target to reduce emissions in 2025 by 50-54% compared to 1990, and an emissions gap of 10.1 million tonnes CO_2e compared with the target to reduce emissions in 2030 by 70% compared to 1990. The extra partial effect of higher allowance prices on emissions from refineries of around 0.08 million tonnes CO_2 has been deducted from the emissions gap for 2030, see sections 2.4 and 7.1.

[7] See chapter 11 for a status on Denmark's EU obligations for non-ETS emissions and LULUCF, as well as for renewable energy and energy-efficiency improvements.

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

	1990	2019	2020	2025	2030	2035
CSO22 net emissions (million tonnes CO_2e)	78.0	47.4	44.9	41.4	33.6	30.2
Climate Act reduction target compared to CSO22 (million tonnes of CO_2e)				35.9-39.0	23.4	
Gap compared with reduction target (million tonnes CO_2e)				2.4-5.5	10.1	
CSO22 reduction relative to 1990 emissions	0%	39%	43%	47%	57%	61%
CSO21 reduction relative to 1990 emissions	0%	40%	43%	47%	55%	

Note: Emissions in target years and the remaining emissions gap have been calculated as annual values in the table. The extra partial effect of higher allowance prices on emissions from refineries of around 0.08 million tonnes CO_2 has been deducted from the emissions gap for 2030. However, for technical modelling reasons, the extra partial effect has not been reflected in the other emissions estimates in CSO22.

Pursuant to the Climate Act, the reduction targets in both 2025 and 2030 must be calculated as three-year averages to minimise fluctuations in individual years. Emissions in target years and the associated emissions gap have been calculated as annual values in table 2.1, among other things because the projection of energy-related emissions assumes that all projection years are 'normal years'.

The emissions gap for 2025 in CSO22 has increased by around 0.3 million tonnes CO_2e compared with CSO21, while the emissions gap for 2030 has fallen by around 1.7 million tonnes CO_2e. This development is the result of a combination of new policy measures, updated expectations about price and market developments, and an updated data basis.[8]

New policy measures included in CSO22

Important new policy measures in CSO22 include[9]:

- Agreement on a green transition of the agricultural sector and Denmark's National CAP Strategic Plan.
- The "Denmark Forward" 2035 infrastructure plan agreement and the agreement on regulation of the EV charging market, as well as the green transport pool realisation agreement, etc.
- Agreement on an additional 2GW offshore wind deployment, agreed as part of the 2022 Finance Act.
- Agreement on a technology-neutral tendering procedure for negative emissions, agreed as part of the 2022 Finance Act.

The effect of these agreements on sector emissions are described in brief in section 2.4 and in more detail in the subsequent sector chapters and underlying sector memoranda. As mentioned above, the energy islands have not been included in this

[8] Furthermore, the methodological approach has been updated in some areas, and this may also have influenced some of the results. See appendix 5 for a comparison between net emissions in CSO22 and CSO21 for the entire period 1990 to 2030.

[9] See table 1 in CSO22 memorandum on assumptions 2A.

year's basic scenario, because establishment of these islands depends on measures that have yet to be decided and therefore cannot be included as frozen policy. The agreement from March 2022 on a tendering procedure to promote hydrogen and green fuels (Power-to-X) has also not been included in CSO22, as the agreement was concluded after the cut-off date for including measures in the report.

Updated expectations about price developments

The emissions in CSO22 are also affected by updated expectations about the CO_2 allowance price and fossil-fuel prices. The CO_2 allowance price level in 2021 was more than double that presented in CSO21, and CSO22 therefore assumes a CO_2 allowance price as high as up to DKK 750 per tonne in 2030 (see CSO22 memorandum on assumptions 3B). In the short term, fossil fuel prices are also at a higher level in CSO22 than in CSO21, particularly the price of natural gas (see CSO22 memorandum on assumptions 3A). However, note that the price scenarios for CSO22 have been fixed from end 2021, and that they therefore do not reflect the significant trend in fuel prices during the first quarter of 2022.

Updated expectations about market developments

In addition to developments in prices, updated expectations about market developments also have significance for the development in emissions in CSO22. In this year's report, expectations have been updated about:

- The range of electric cars available in the market, which has significance for the rate at which electric cars and electric vans and lorries replace vehicles with conventional combustion engines in the transport sector.
- Demand on agriculture markets, which is significant for the amount of livestock and crops produced by the agriculture sector.
- The activity level in cement production.

Updated data basis

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 CSO22 include:

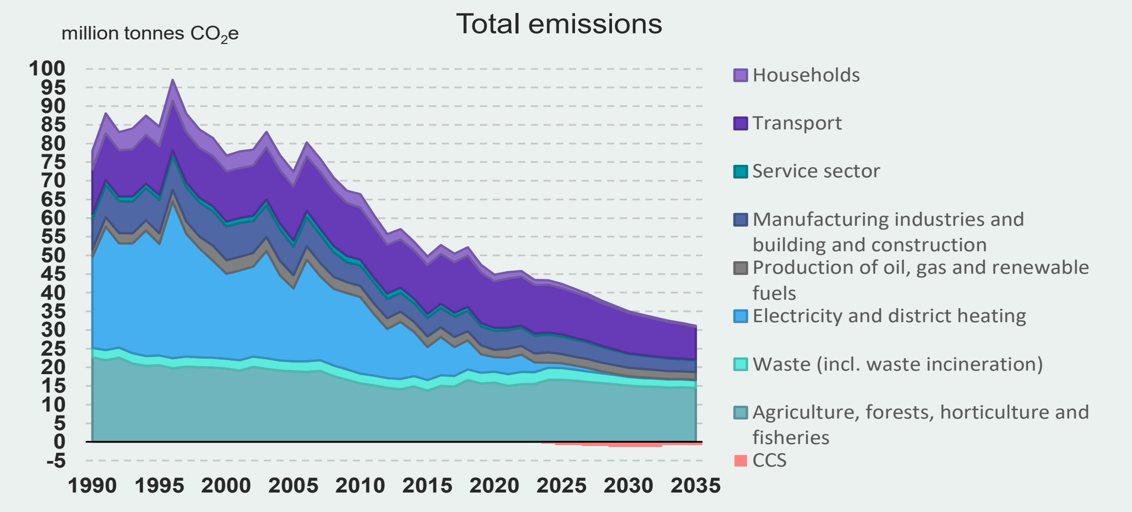
- A higher future leakage rate from biogas plants as a result of a measurement project (see CSO22 memorandum on assumptions 9B)
- Updated assumptions for calculations, for example in the form of a new assumption about higher future temperatures, which lead to reduced net removals by mineral soils in agriculture (see CSO22 memorandum on assumptions 10C)
- Updated data on the carbon content of and expected removals by forest land, the share of felled trees stored in wood products, expectations about new afforestation, and changed management practices, for example through

conversion to virgin forest and nature areas, all of which lead to expected increased net removals

2.2 Trends in emissions across sectors

Developments in total net emissions are a result of developments in the various underlying sectors. Figure 2.2 illustrates developments in the individual sectors from 1990 up to 2020 and the expected developments in the projection period from 2021 to 2035 for these sectors, as well as for carbon capture and storage (CCS).

Figure 2.2: Total emissions by sectors, and CCS



Note: In CSO22, CCS is dealt with as negative emissions not broken down by sectors (see section 2.4).

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 2020, the sector accounted for only 9% 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.[10] 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 will decrease in future as total emissions from the electricity and district heating sector are reduced as a consequence of phasing-

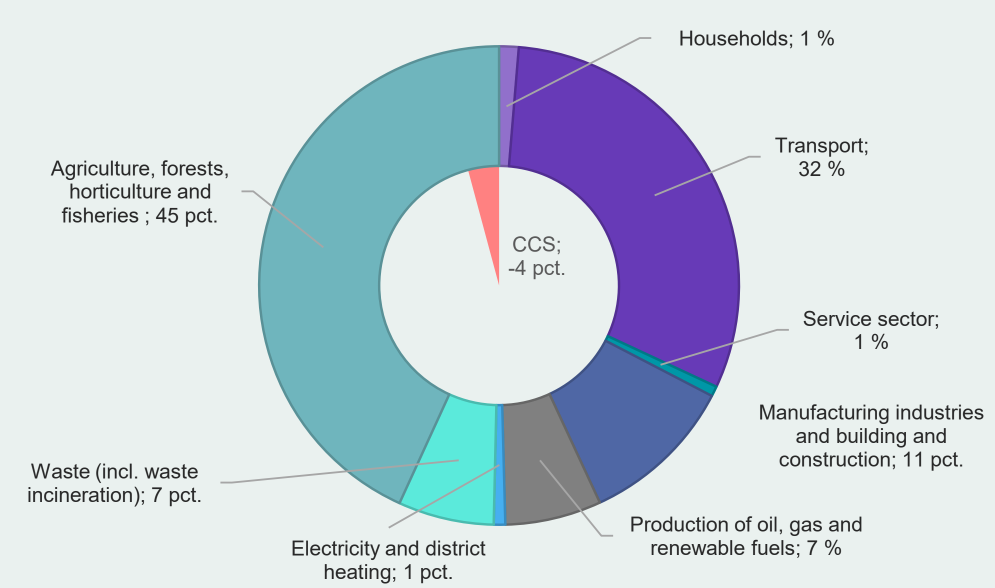
[10] Waste incineration also contributes to electricity and district heating production. If emissions from waste incineration are included with emissions from the electricity and district heating sector, these sectors accounted for 12% of net emissions in 2020 and are expected to make up 7% in 2025 and 3% 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).

out fossil power plants and transitioning 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 forests, as well as energy consumption by the sector, have therefore gone from contributing around 25% of total emissions to contributing 35% of total emissions in 2020. In 2025, this sector is expected to account for 40% of net emissions, while in 2030 the sector's share of total emissions is expected to have increased further to 45%. Similarly, the transport sector's share of total net emissions grew from 15% in 1990 to 28% in 2020, and in 2025 and 2030, 30% and 32%, respectively, of net emissions are expected to stem from the transport sector.

How total emissions in 2030 distribute across sectors is illustrated in figure 2.3.[11]As can be seen from the figure, emissions in 2030 will be concentrated on relatively few sectors. It is expected that more than 75% of the total net emissions of 33.6 million tonnes CO_2e will stem from either agriculture, forests, horticulture and fisheries or the transport sector.

Figure 2.3: Total net emissions in 2030 by sector



Note: In CSO22, CCS is dealt with as negative emissions not broken down by sectors (see section 2.4).

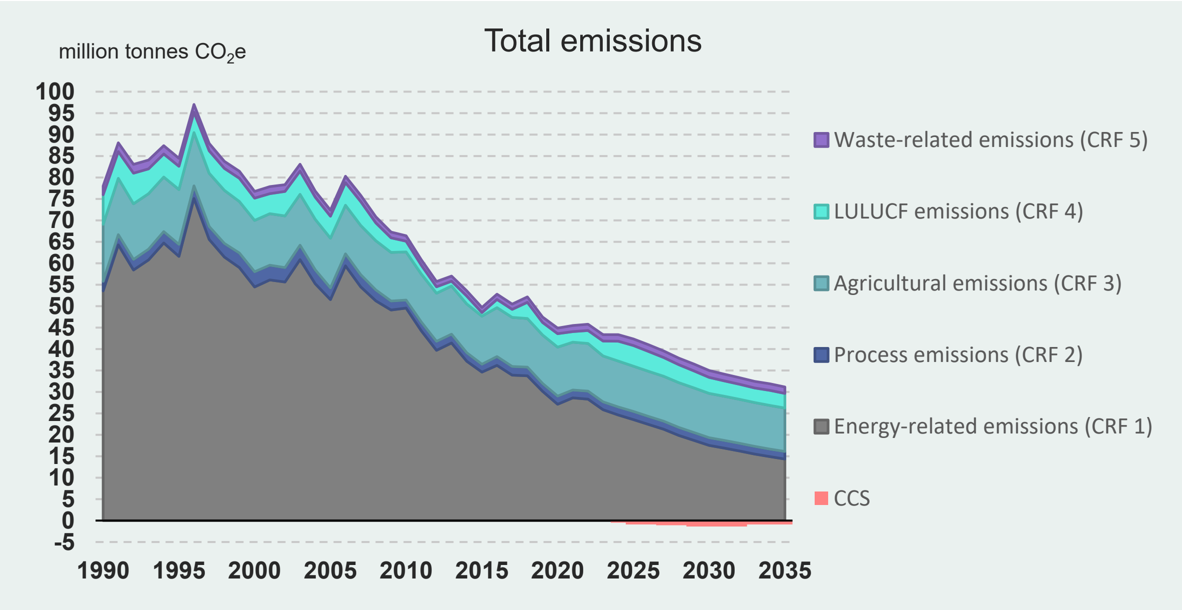
[11] Note that the sectoral divisions in CSO22 have been changed slightly compared to CSO21, in that F gases have been broken down by sectors in CSO22 (see the distribution key for F gases described in CSO22 memorandum on assumptions 9C about F gases). However, this has only very limited significance for the sectors' shares of total emissions in 2030, since F gases will account for only around 0.5% of total net emissions in 2030.

2.3 Trends in emissions across types of emission

Greenhouse gas emissions across sectors stem from several different sources and types of activity. Under the Common Reporting Format (CRF) used for international reporting to the UN and the EU, emissions are divided into five overarching CRF categories: 1) energy-related emissions, 2) process emissions, 3) emissions from agricultural processes, 4) LULUCF emissions and 5) waste-related emissions.[12]

Almost all emissions from households, transport and production of oil, gas and renewable fuels are energy-related emissions, while the service sector and the manufacturing and building and construction sector have both energy-related emissions and process emissions.[13] Emissions from the waste sector include both energy-related emissions from waste incineration and waste-related emissions from landfills, wastewater, composting and biogas leakage, while the majority of emissions from agriculture, forests, horticulture and fisheries stem from agricultural processes (i.e. digestion by livestock, manure management and fertiliser use), as well as from agricultural land use.[14]

Figure 2.4: Total emissions by CRF categories, and CCS



Energy-related emissions

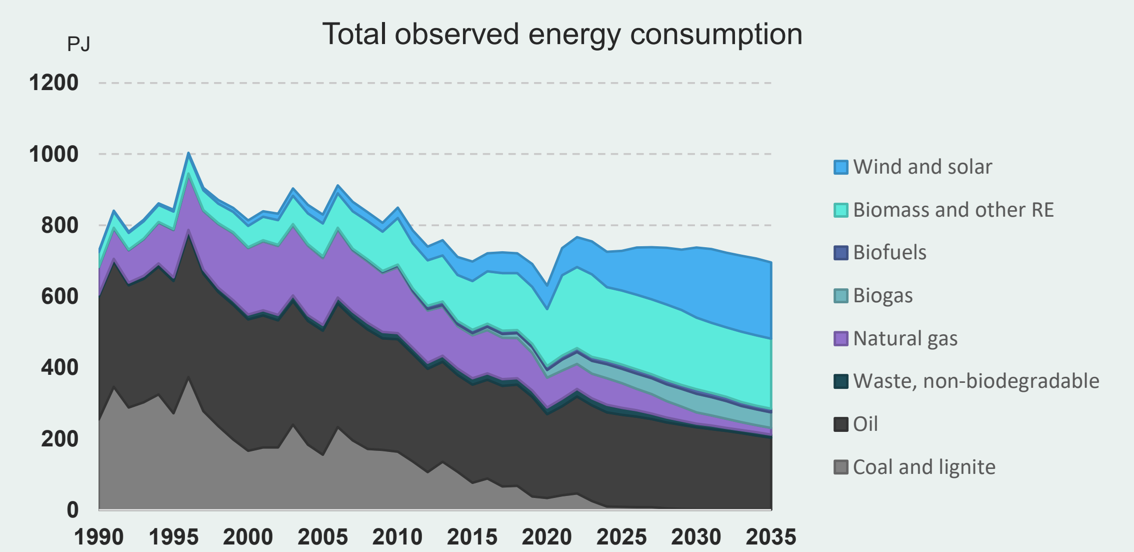
Up to 2015, total energy-related emissions across sectors have typically constituted between 70% and 75% of total Danish greenhouse gas emissions. However, since

[12] See also Appendix 5.1 in CSO22 memorandum on assumptions 2B.
[13] Process emissions from the service sector comprises F gases, see CSO22 sector memorandum 5A and CSO22 memorandum on assumptions 9C.
[14] Historically, forests have contributed significantly to CO_2 removal, but this contribution will be less significant during the projection period, and during the period 2025 to 2029, small net emissions are expected from forests.

then, the energy-related emissions' share of total emissions has dropped, and this trend is expected to continue in the projection period. In 2025, energy-related emissions are therefore expected to account for around 55% of total emissions, in 2030 the share will have fallen additionally to 50%, and in 2035 it will be close to 45%. In future, the majority of energy-related emissions will come from the transport sector, as the transport sector's share of energy-related emissions will have gone from 45% in 2019 to 53% in 2025 and 61% 2030. The transport sector's share of energy-related emissions will increase even though total emissions from the sector are expected to fall during the projection period.

Developments in energy-related emissions depend on total energy consumption as well as on the share of renewable energy in energy consumption. Figure 2.5 shows the energy mix and developments observed in Danish energy consumption from 1990 to today, and onwards up to 2035.

Figure 2.5: Total observed energy consumption by type of energy (PJ)



Note: The majority of natural gas and biogas will be blended into the gas system and will become mains gas for end consumption.

Renewable energy covers a large number of renewable energy sources, from wind and solar over solid biomass to liquid biofuels 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. Biomass burning is considered CO_2 neutral under the UN IPCC methodology, while biogenic energy-related CO_2 emissions are to be reported as a so-called memo item (see memorandum on assumptions 2B).

The biogenic CO_2 emissions from total Danish consumption of biomass for energy-related purposes are shown in Appendix 6.[15]

While emissions associated with electricity and district heating production are ascribed 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 ascribed to the consuming sectors. Emissions from these sectors are therefore determined by the renewables share in mains gas and transport fuels. As can be seen from table 2.2, the renewables shares in mains gas and transport fuels will increase during the projection period, for transport fuels, from 6% in 2020 to 9% in 2030, and for mains gas, from 16% in 2020 to 75% in 2030 and 92% in 2035.[16] Towards the end of the projection period, it is therefore expected there will be relatively few emissions associated with consumption of mains gas.

Table 2.2: Renewables shares in electricity consumption, mains gas and transport fuels, as well as total renewables share

	2019	2020	2025	2030	2035
Renewables share in electricity consumption (RES-E)	65%	65%	93%	109%	102%
Renewables share in mains gas	10%	16%	38%	75%	92%
Renewables share in transport fuels	5%	6%	7%	9%	8%
Total renewables share (RES) (before sales)	37%	42%	51%	64%	67%

Note: Numbers in the table are rounded. Total RES is calculated before statistical transfers between Denmark and other EU Member States. After statistical transfers, RES was 32% in 2020 (see CSO22 sector memorandum 11B).

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 CSO22 sector memorandum 4B). The renewables share in mains gas, on the other hand, will change with changes in the consumption of mains gas. This is because the renewables share in mains gas consists of upgraded biogas, and the amount of biogas produced depends on the demand, assuming that the demand is determined by the relevant subsidy schemes (see CSO22 memorandum on assumptions 7C and sector memoranda 7A and 7B). 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.

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

[16] 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.

The renewables share in electricity supply is also projected to increase, from 65% in 2020 to 109% in 2030.[17] Note that meeting the target in the Power-to-X strategy and establishing the energy islands, which have not been included in the CSO22 basic scenario, will significantly increase both the demand and the supply of electricity relative to the levels projected in CSO22.

In CSO22, the renewables share in total energy consumption (before statistical transfers) will increase from 42% in 2020 to 64% in 2030 and 67% in 2035.

Emissions from industrial processes, agricultural processes, land and waste incineration (excluding waste incineration)
Non-energy-related emission types include:

- Process emissions, which are emissions from industrial processes and emissions from use of appliances, etc. (in the form of F gases). Process emissions were 1.8 million tonnes CO_2e in 2019 and are expected to be at the same level in 2030. Process emissions from cement production contribute around 1.3 million tonnes CO_2e annually in the projection period and therefore comprise the majority of total process emissions.
- Emissions from agricultural processes, which include emissions from animal digestion, manure management and fertiliser use. Emissions from agricultural processes were 11.4 million tonnes CO_2e in 2020 and are expected to have been reduced to 10.3 million tonnes CO_2e in 2030.
- LULUCF emissions, which include emissions and removals by agricultural land and forests, as well as other land and harvested wood products. LULUCF net emissions were 3.1 million tonnes CO_2e in 2020 and are expected to increase to 3.7 million tonnes CO_2e in 2030.
- Waste-related emissions, which comprise emissions from landfills, wastewater and composting, as well as leakage from biogas plants. Waste-related emissions were 1.2 million tonnes CO_2e in 2019 and are expected to increase to 1.6 million tonnes CO_2e in 2030.

Emissions from agricultural processes therefore account for the majority of non-energy-related emissions, and emissions from agricultural land also account for the majority of LULUCF emissions. In 2025, emissions from agricultural processes and agricultural land are therefore expected together to account for around 80% of non-energy-related emissions, and this will also be the case in 2030 and 2035.[18] In step with the general fall in energy-related emissions, the relative significance of non-

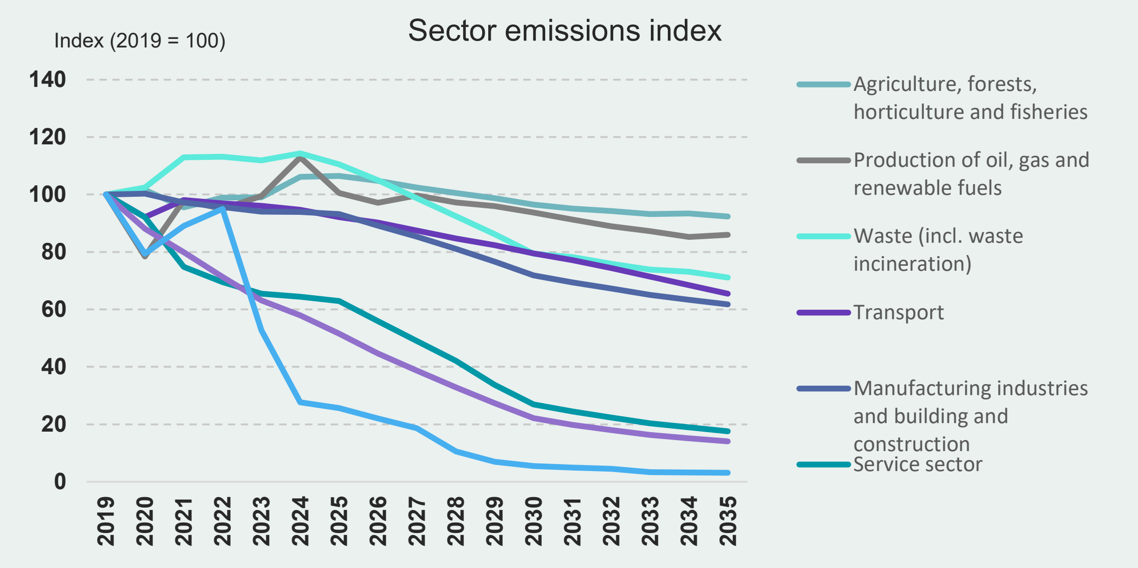
[17] RES-E is a measure of surplus/shortage of renewables-based electricity production in the Danish electricity system compared to Danish electricity demand, and therefore RES-E can exceed 100%. RES-E was at 97% in 2030 in CSO21. The increase in RES-E for the period around 2030 is largely the result of the increased offshore wind deployment of 2GW decided as part of the 2022 Finance Act.
[18] Note that total emissions from the agriculture, forests, horticulture and fisheries sector also include the sector's energy consumption, as well as LULUCF emissions and removals by forests, other land and harvested wood products (see chapter 10).

energy-related emissions will increase, and a significant part of these emissions stem from production processes in agriculture and from agricultural land.

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 section describes sector emissions compared to 2019, as emissions in 2020 for some sectors are affected by the Covid-19 pandemic.

Figure 2.6: Trends in sector emissions 2019-2030 (2019 = index 100)



Note: CCS is not illustrated in this figure, as the technology was not established in 2019.

Emissions from agriculture, forests, horticulture and fisheries were 15.7 million tonnes CO_2e in 2019. Emissions are expected to increase to 16.7 million tonnes CO_2e in 2025, after which they will decrease to 15.1 million tonnes CO_2e and 14.5 million tonnes CO_2e in 2030 and 2035, respectively, corresponding to a fall of 4% in 2030 and 8% in 2035 compared to 2019. Developments in total sector emissions distribute differently across the individual subsectors.

Thus, emissions from agricultural processes will fall from 11.3 million tonnes CO_2e in 2019 to 10.3 million tonnes CO_2e in 2030, amongst other things due to measures under the 2021 agriculture agreement such as reduction requirements for livestock digestion, more frequent slurry flushing, extensification, and set-aside measures for agricultural land, etc. LULUCF emissions will increase from 2.9 million tonnes CO_2e in 2019 to 4.8 million tonnes CO_2e in 2025[19], after which they will fall again to 3.7 million tonnes CO_2e in 2030. The increase up to 2025 is largely the result of forests going from contributing net removals of 2.5 million tonnes CO_2e in 2019 to net emissions of

[19] However, LULUCF emissions are only 2.4 million tonnes in 2021, amongst other things because 2021 was a relatively cold year, which increases removals by mineral soils.

0.3 million tonnes CO_2e in 2025. The drop in LULUCF emissions from 2025 and onwards is due mainly to set-aside and rewetting carbon-rich soils, as well as to laying out catch crops. Furthermore, emissions from forests are projected to decrease, and from 2030 and onwards forests are again expected to contribute a slight uptake.

Emissions from the transport sector were at 13.5 million tonnes CO_2e in 2019. Transport emissions are expected to fall to 12.4 million tonnes CO_2e in 2025 and 10.7 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 8.8 million tonnes CO_2e, corresponding to a decrease of almost 35% compared to 2019. 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. With regard to the transition from conventional to electric vehicles, there is projected almost 740,000 electric cars and 270,000 plug-in hybrid cars in 2030, amongst other things due to technological and market developments, including a broader range of electric cars. In 2030, it is expected there will be around 57,000 electric vans and 8,000 plug-in hybrid vans, 2,600 electric lorries and 2,700 electric busses. 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 2019 to zero from 2031 and onwards.

Emissions from manufacturing industries and building and construction will fall from 5.1 million tonnes CO_2e in 2019 to 4.7 million tonnes CO_2e in 2025 and 3.7 million tonnes CO_2e in 2030, and are expected to be at 3.1 million tonnes CO_2e in 2035. The fall is due to a fall in energy-related emissions from the sector (from 3.6 million tonnes CO_2e in 2019 to 1.5 million tonnes CO_2e in 2035). Process emissions from the sector, most of which stem from cement production, will increase from 1.4 million tonnes CO_2e in 2019 to almost 1.7 million tonnes CO_2e in 2025 and will stay at this level up to 2035. Amongst other things, this is due to expected increased cement production in Denmark due to an updated assessment on the basis of recent years' production and demand trends, as well as assessments of the total production capacity (see CSO22 memorandum on assumptions 6B).

The expected increase in cement production in Denmark despite rising allowance prices should be considered against the backdrop of the rising allowance prices also affecting cement producers in other parts of the EU.

Emissions from the electricity and district heating sector will fall from 4.9 million tonnes CO_2e in 2019 to 1.3 million tonnes CO_2e in 2025. In 2030, the sector is expected to emit 0.3 million tonnes CO_2e, and in 2035 just 0.15 million tonnes CO_2e. The background for the significant decrease in emissions is primarily in the phase-out of 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. Early in the projection period, rising fuel prices will lead to higher electricity prices, which will make it beneficial for Danish electricity producers to increase their thermal electricity production. In some individual years, this will lead to a higher share of electricity and district heating production based on coal, mains gas and, in particular, biomass, until the share once more falls later in the projection period as a result of competition from increased production of solar and wind power.

The energy islands are not included in the CSO22 basic scenario. Therefore, the system and climate consequences of the energy islands for the Danish electricity and district heating sector have been illustrated in a partial sensitivity calculation, which assumes no change in domestic electricity consumption. In the sensitivity calculation, the energy islands mean that the renewables share in electricity consumption in 2030 increases from 109% to 123%, and in 2035 from 102% to 138%. The energy islands are expected to supply a large surplus of green electricity, which 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 calculation also shows that, on their own, the energy islands will have very little significance for Danish greenhouse gas emissions, as the scope of fossil electricity production in Denmark will be limited towards the end of the projection period.

Emissions from the waste sector were 2.9 million tonnes CO_2e in 2019. Up to 2024, emissions from the waste sector will increase to 3.3 million tonnes CO_2e, after which they will decrease to 2.3 million tonnes CO_2e in 2030 and 2.0 million tonnes CO_2e in 2035. Amongst other things, the development is due to higher emissions associated with methane leakage from biogas plants as a result of a measurement programme having prompted an upwards adjustment of the leakage rate for biogas plants (see CSO22 memorandum on assumptions 9B and sector memorandum 9B). The upwards adjusted leakage rate means higher expected biogas leakage emissions, and these are expected to increase in step with increasing biogas production up to 2030. Furthermore, a small increase is expected in emissions from waste incineration; from 1.6 million tonnes in 2019 to 1.7 million tonnes in 2024. After this, emissions from waste incineration will fall to 0.7 million tonnes in 2030 as waste incineration capacity is reduced to match smaller Danish waste volumes as a consequence of the 2020 agreement on a climate-neutral waste sector, for example. Increased separation also means that the fossil share in Danish waste volumes will be reduced (see CSO22 memorandum on assumptions 9A and sector memorandum 9A).

Emissions from production of oil, gas and renewable fuels include emissions associated with extraction in the North Sea and emissions from refineries, and in 2019 these made up a total of 2.4 million tonnes CO_2e. Emissions from the sector will peak in 2024 at 2.7 million tonnes CO_2e, after which they will fall to 2.3 million tonnes CO_2e in 2030 and 2.1 million tonnes CO_2e in 2035. The higher emissions during the mid-2020s are due to increased own consumption from extraction activities, and this is linked to postponement of commissioning of the Tyra complex as well as commissioning of a number of other, smaller projects, in which emissions are highest in the start of the operating phase. Furthermore, note that emissions from refineries are covered by the ETS, which means that allowance price developments could have an effect that has not been fully reflected in the sector's emissions in CSO22, because, in CSO22, refineries have been projected to follow a flat curve from the 2019 level (see also chapter 7 and memorandum on assumptions 7B). The extra partial effect on emissions from refineries caused by higher allowance prices is assessed to be around 0.08 million tonnes CO_2. For technical modelling reasons, in CSO22, the extra partial effect is not reflected in the estimate of emissions by refineries; it has, however, been deducted from the emissions gap for 2030 (see section 2.1).[20]

CCS (carbon capture and storage)

In CSO22, CCS is also included as a source of emissions reduction not broken down by sectors. CCS is expected to be realised as a consequence of the CCUS pool (from the 2020 climate agreement for energy and industry, etc.), and the technology-neutral tendering procedure for negative emissions (from the 2022 Finance Act). The expected annual CO_2 emissions reduction effect from CCS is illustrated in table 2.3 below.

Table 2.3: Expected annual CO_2 emissions reduction effect from CCS

CO_2 (million tonnes)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
CCUS pool	0	0	0	0	0.4	0.4	0.6	0.6	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Pool for negative emissions	0	0	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0	0	0
Total reduction effect	0	0	0	0.5	0.9	0.9	1.1	1.1	1.4	1.4	1.4	1.4	0.9	0.9	0.9

Source: CSO22 memorandum on assumptions 7E: CCS (2022)

CCS can ensure zero emissions from fossil sources or process sources, or negative emissions, if the technology is used to capture biogenic emissions. Due to the large uncertainty about future developments for CCS in Denmark, CSO22 does not include a specific assessment of which sectors will use CCS and will therefore have their emissions reduced. In CSO22, CCS is therefore dealt with as a separate source of negative emissions not broken down by sectors. Because CCS is not broken down by sectors, CCS has also not been included as an integrated part of system calculations for CSO22, and derived effects (e.g. with regard to energy consumption, etc.) will therefore not be reflected in the projected figures.

2.5 Uncertainty

As mentioned in chapter 1, it is important to consider the uncertainty associated with the projection when looking at the results presented in CSO22. This applies to the general uncertainty that will always be there when projecting greenhouse gas emissions, as well as the specific uncertainty linked to both derived effects of the Covid-19 pandemic and derived effects of developments in Ukraine.

[20] The possibilities for fine-tuning how emissions from refineries are managed in the models behind the climate projections will be examined before publication of CSO23.

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 source of general uncertainty in the projection concerns uncertainty about investment behaviour, including, in particular, the phase-in rate for new technologies (e.g. electric cars 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 will be uncertainty about the scope of the effect of the CCUS subsidy pool and the technology-neutral tendering procedure for negative emissions (see CSO22 memorandum on assumptions 7E).

Finally, there is general uncertainty associated with the projection's assumptions, including assumptions about economic growth, price developments for resource inputs and technological advances. These factors will also be affected by the Covid-19 pandemic and developments in Ukraine.

The Covid-19 pandemic and developments in Ukraine
There continues to be considerable 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 2020 is the most recent statistical year in CSO22 but that, in many cases, the underlying projection is based on 2019, which is assessed to be a more fitting and true projection basis. As CSO22 also reports actual observed emissions for 2020, in many cases, this means that figures and tables show a 'dip' in 2020.

The developments in Ukraine have had significant derived effects on a number of international markets, not least the energy markets. The assumptions behind CSO22 were determined at the end of 2021, and the significant trends in energy prices seen in the first quarter of 2022 are therefore not reflected in the CSO22 results.[21] The same applies to the government's proposal for a greener and more secure Denmark, *Denmark can do more*, and the green tax reform proposal. These elements cannot be included until in CSO23.

Sensitivity calculations
The following sector chapters include examples of important uncertainties and, in some cases, sensitivity calculations for the relevant sectors. The underlying sector memoranda provide further in-depth descriptions of these. Cross-cutting sensitivity calculations on fossil fuel prices and the CO_2 allowance price will be in a separate memorandum to be published after publication of CSO22.

[21] However, energy prices had already increased considerably towards the end of 2021 and these increases are reflected in CSO22 fuel price assumptions, see CSO22 memorandum on assumptions 3A.

3 Households

The household sector comprises all citizens residing in Denmark. About 5.9 million people live in around 2.7 million homes[22]. All homes need heating, and some have this need met through collective district heating, while others have to rely on individual heating technologies such as gas-fired boilers and heat pumps[23]. Furthermore, all households use a variety of electrical appliances for lighting, washing and cleaning, cooking and food storage, as well as for entertainment.

In CSO22, the household sector includes emissions linked to household consumption of individual heating, while emissions related to district heating and electricity consumption are included in the electricity and district heating sector as described in chapter 8. The household sector also covers emissions from patio heaters based on gas, petrol-driven lawn mowers and similar. Furthermore, household emissions in CSO22 now also cover F gases linked to household use of appliances, etc. (see CSO22 memorandum on assumptions 9C).

[22] Source: Statbank Denmark, Statistics Denmark. FOLK1A tables: *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.
[23] 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 2019 and 2020, the household sector emitted 2.1 and 1.9 million tonnes CO_2e, respectively, corresponding to around 4% of total Danish emissions in both years.

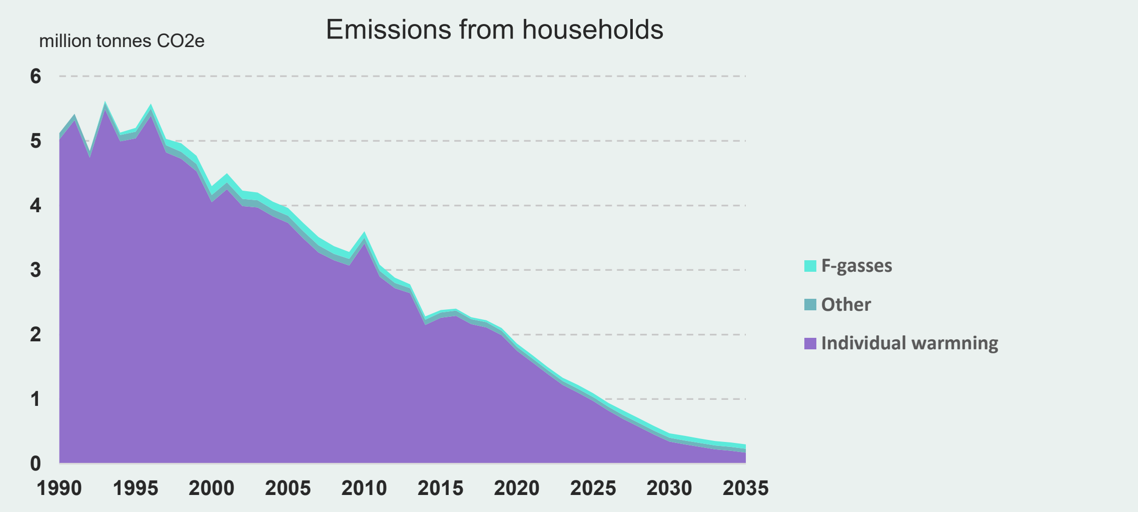
In 2025, 2030 and 2035, the sector is expected to emit 1.1, 0.5 and 0.3 million tonnes CO_2e, respectively, corresponding to 3%, just over 1% and 1%, respectively, of total Danish emissions. The expected changes in sector emissions are due, in particular, to the following factors:

- Individual heating in households will become less CO_2-intensive for three reasons: Some individual heating technologies will be converted to collective district heating, due to increased district heating network deployment. For households that continue using individual heating systems, some will convert away from oil- and gas-fired heating to heat pumps. Emissions are falling for households that still have gas-fired boilers because of a higher renewables share in mains gas.
- Energy-efficiency improvements in the form of improvements in existing buildings and better building standards for new buildings mean that final energy consumption for heating will not increase, even though the heated floor area will. Conversion to district heating and heat pumps also means that the heating demand of households will be covered in a more energy-efficient manner.

3.1 Emissions from the household sector

Household emissions stem from a subset of energy consumption by the sector, i.e. the share of energy consumption that includes individual heating such as oil- and gas-fired heating, as well as energy consumption by patio heaters, petrol-powered lawnmowers and similar[24]. Furthermore, CSO22 includes emissions of F gases, which primarily comprise household use of refrigerants in heat pumps.

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



Note: Historical values for energy consumption are stated as the actual figures. Other includes patio heaters, petrol-powered lawnmowers and similar.

[24] Household consumption of fuel for transport, including petrol, diesel and electricity for electric cars, is described in chapter 4 and sector memorandum 4A on transport.

Total emissions by households for the period 1990-2035 are illustrated in figure 3.1.

As the figure shows, total emissions from the sector are expected to fall by 78% from 2019 to 2030 and the fall is expected to continue to 2035, when households are expected to emit only 0.3 million tonnes CO_2e.

3.2 Household energy consumption, efficiency improvements and changes in technology

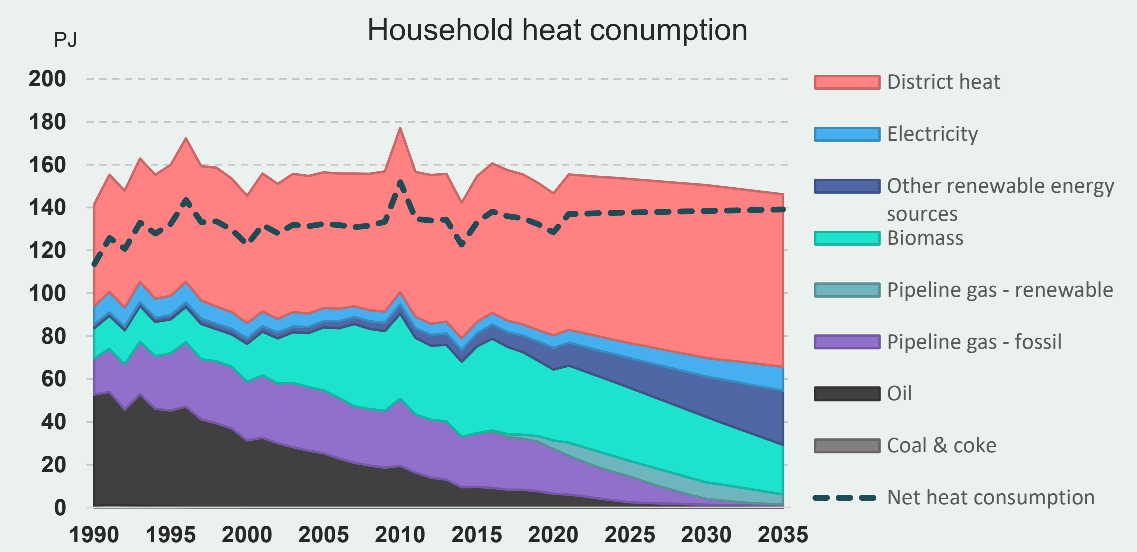
Although households accounted for only 4% of total emissions in 2019, the sector is still responsible for 30% of total final energy consumption. Energy consumption in households consists of around 85% space heating and about 15% electricity consumption.

Final consumption for space heating and hot water is expected to increase slightly up to 2025 and then fall (see CSO22 sector memorandum 3A). Electricity consumption for lighting and appliances peaked in 2020 and then declined. No new policy measures aimed at household heating were adopted in 2021. Therefore, expected developments after 2020 will be driven by political agreements that were also included in CSO21, including tax adjustments to make electric heating less costly, changes in regulations to remove obstacles to converting gas areas to district heating, as well as the four subsidy pools to phase out oil- and gas-fired heating, which received additional funds in the 2021 Finance Act: The building pool, the scrapping scheme, the district-heating pool and the decoupling scheme. CSO22 does not take account of the additional funds earmarked in the agreement on a targeted heating cheque of February 2022 to secure quicker phase-out of fossil heat in Danish homes. The market price of natural gas has been high since autumn 2021, and the situation in Ukraine has increased uncertainties in energy markets, which together may have a lasting effect on households' choice of heating.

Household heating - choice of technology
Developments in emissions and energy consumption associated with heating in households are driven by several factors, including household choice of heating, the floor area of households to be heated, and the condition and age of the building. In many places, households' choice of heating technology will be restricted depending on whether the specific household has access to a district heating grid or a mains gas grid. Previously, there were also limitations associated with restrictions on consumers such as mandatory grid connection and/or an obligation to stay with district heating or mains gas. Following the 2018 Energy Agreement, the option to impose new restrictions on consumers was abolished. Existing restrictions on consumers to remain on the mains gas grid were terminated as a result of the *2020 Climate Agreement for Energy and Industry etc.* and the last (obligation to connect to power and remain) will be repealed from 1 July 2022. Existing restrictions to remain on district heating will be maintained.

This trend is expected to be towards more district heating and similar, less individual types of heating in the future. In 2020, slightly more than half of all residential buildings had district heating as their primary heating technology. In 2030 this is expected to be around 65% and the increase will continue up to 2035. With regard to the individual heating technologies, heat pumps are expected to increase, whilst fewer residential buildings are expected to be heated by oil-fired boilers, gas-fired boilers biomass installations or electric radiators. Heat pumps were the primary heating technology in 8% of residential buildings in 2020, and this percentage is expected to rise to 14% in 2030 and 20% in 2035. Gas-fired boilers and oil-fired boilers were the primary heating technology in 21% and 4% of residential buildings in 2020, respectively, and these percentages are expected to drop to 10% and 1% in 2030, respectively. In 2030, around 185,000 residential buildings are expected to have oil-fired or gas-fired boilers as their primary heating technology. It is also expected that around 260,000 residential buildings will have heat pumps and that around 1.2 million buildings will have district heating as their primary heating technology in 2030. It is important to note that these expectations are based on fuel prices from December 2021, i.e. before the sharp price increases as a consequence of the situation in Ukraine, and before the Government's presentation of *Denmark can do more II*.

Figure 3.2: Final heating consumption by households by energy product for 1990-2035 in PJ



Notes: Historical values for energy consumption are stated as the actual figures. Other renewable energy includes ambient heat (heat pumps) and solar energy. Mains gas is divided into a fossil share and a renewables share based on the overall percentage of biomethane in the system.

Figure 3.2 shows that household heating is expected to be increasingly covered by district heating. With regard to individual heating technologies, heating based on mains gas and oil is falling. Biomass has also fallen, but is expected still to account for 20% of final heating consumption in 2030. Other renewable energy includes ambient heat from heat pumps and a little solar energy. Other renewable energy accounts for 6% for final heating consumption in 2019, and this is expected to rise to 13% in 2030. Electricity for electric radiators and heat pumps is expected to double between 2019 and 2035. The anticipated increase covers a slight drop in electricity consumption for electric radiators and more than double the electricity consumption for heat pumps between 2019 and 2035. In 2030, the expected energy mix in households for heating will primarily consist of district heating, biomass and heat pumps, supplemented by electricity and mains gas. Mains gas comprises natural gas and biomethane, and emissions associated with consumption of mains gas depend on the percentage of biomethane in mains gas (see CSO22 sector memorandum 7B).

Household heating - energy efficiency

The shift from oil- and gas-fired heating towards more efficient supply solutions such as district heating and heat pumps has contributed to reducing the difference between final energy consumption and net heating consumption, which consists of losses in conversion and distribution components in individual household heating installations. In 1990, 20% of the final energy consumption used to produce space heating and hot water for Danish houses was not utilised to heat dwellings. In 2030, this loss is expected to be just 8%, see figure 3.2.

The heated floor area is expected to increase by around 3% in single-family houses, and about 12% in blocks of flats from 2020 to 2030. Even though floor area will increase, final energy consumption for heating is expected to fall by about 7% for single-family houses, and to increase only slightly for blocks of flats in 2030. Heating consumption per square metre in homes has generally fallen since 2010 and is expected to fall further up to and beyond 2030. Developments are affected by households improving the energy efficiency of existing buildings on an ongoing basis, and that new buildings require less energy per square-meter for heating than the existing building stock. Furthermore, as mentioned above, a shift is expected towards heating technologies with a smaller conversion loss in heating installations such as heat pumps and district heating.

Household heating - emissions

CO_2e emissions associated with heating both single-family houses and blocks of flats are expected to drop by about 90% up to 2030, and the drop is expected to continue. Conversion away from oil-fired and gas-fired boilers towards heating technologies that emit less CO_2e is expected to contribute a reduction of around 1.1 million tonnes CO_2e in 2030 relative to 2019. In addition to the reductions from converting to cleaner heating technologies, emissions from households' individual heating are expected to be reduced as a result of an increased renewables share in mains gas. Compared to a situation in which mains gas is 100% fossil-based, the expected renewables share in mains gas will contribute with a reduction in emissions by households of 0.5 million tonnes CO_2e in 2030 relative to 2019.

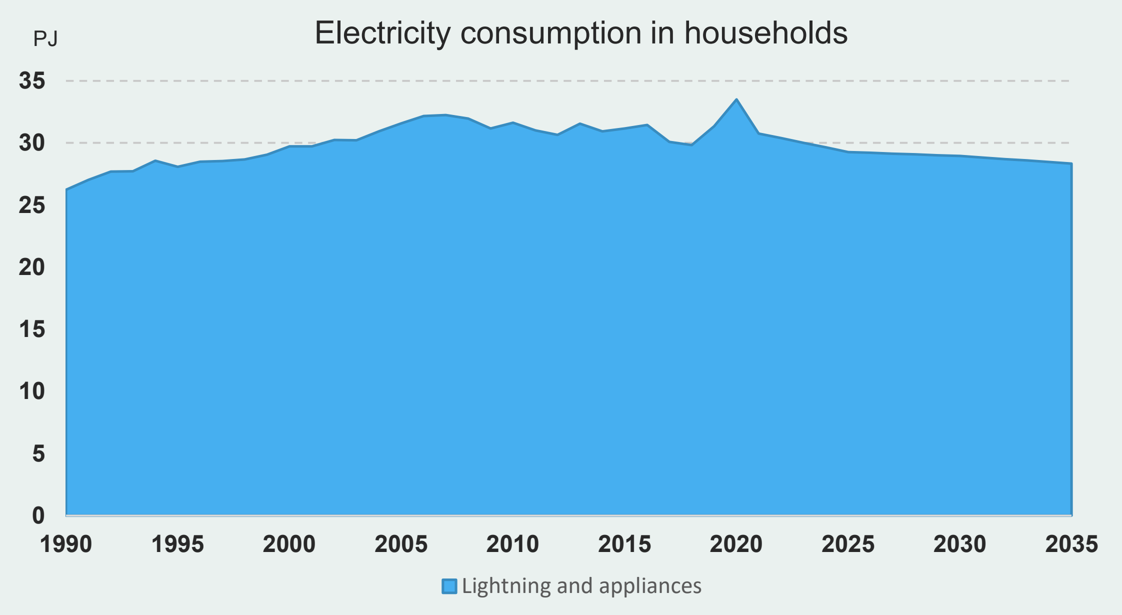
Note that any additional conversions away from mains gas will lead to a corresponding reduction in total consumption of fossil natural gas, and therefore also in total emissions, because the supply of biomethane is assumed to be determined by subsidies for biomethane, and not by the demand for mains gas (see sector memorandum 7B).

Electricity consumption in households

Electricity consumption in households is used for lighting and appliances, as well as for heating with heat pumps and electric radiators. Electricity consumption for heating has been addressed above, so this section is exclusively about electricity consumption for lighting and domestic appliances.

Figure 3.3 shows that electricity consumption for lighting and domestic appliances in households increased by 19% from 1990 to 2019. Electricity consumption increases further in 2020 and is expected to drop after this. The fall will continue after 2025, but at a slower pace. The high consumption in 2020 is due to more working from home in connection with the Covid-19 pandemic. The projection is based on the 2019 level. Developments after 2020 are due to the expected end of the effects of the Ecodesign requirements for the efficiency of electrical appliances in around 2025, for example from replacing old lighting with LED light bulbs

Figure 3.3: Electricity consumption for lighting and domestic appliances in households for 1990-2035 in PJ



Note: Historical values for energy consumption are stated as the actual figures.

Changes in electricity consumption for lighting and domestic appliances are driven by changes in the number of households, the number of appliances per household and the efficiency of the appliances.

The number of households is expected to increase by around 9% up to 2035, corresponding to about 250,000 households. The total drop in electricity consumption for lighting and domestic appliances is composed of an increase in the number of households, more or less unchanged number of appliances per household, and increasing efficiency of all appliances. The expected increase in efficiency is large enough to counteract the increases caused by other drivers, and even large enough to result in falling electricity consumption for lighting and domestic appliances in households.

3.3 Uncertainty

With regard to the household sector, future developments in behaviour comprise significant uncertainty. Households are composed of many different actors with different preferences, and who do not necessarily have the information or competences necessary to make rational decisions regarding choice of heating technology or electricity consumption. 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, there is uncertainty regarding the projection of parameters that are crucial for future energy consumption, e.g. the number of households, number of heated square metres, etc.

4 Transport

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 are partly driven by all the very different needs to transport people and goods, partly by changes in 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 transport of goods divided into the following categories[25]:

- Road transport
- Rail transport
- Domestic aviation
- Domestic shipping
- Other transport (defence and leisure craft)

In 2019, the transport sector emitted 13.5 million tonnes CO_2e, corresponding to around 28% of total Danish emissions. Emissions from the sector are expected to fall to 12.4 million tonnes CO_2e up to 2025, after which they will decrease further to 10.7 million tonnes CO_2e and 8.8 million tonnes CO_2e in 2030 and 2035, respectively.

[25] Domestic aviation and shipping includes 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 2022, which is published in parallel with CSO22.

However, the sector's share of total emissions is expected to remain at around 30%, since total Danish emissions will also become smaller.

The expected developments in the sector's emissions are primarily attributable to the expected developments in road transport because 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:

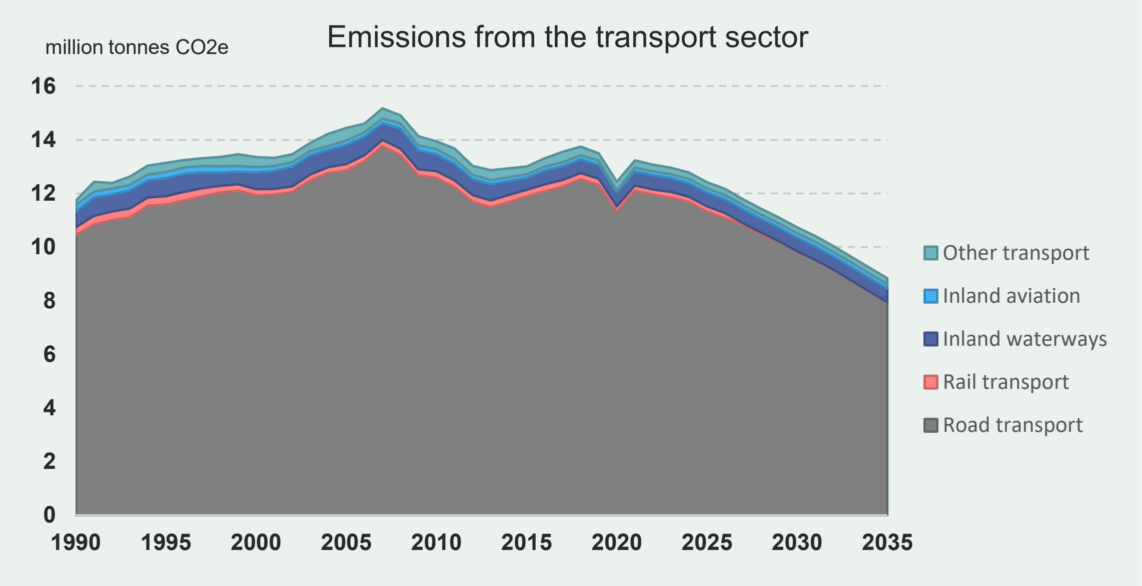
- Growing traffic (number of kilometres driven will increase)
- Electrification of road transport through transition from conventional to electric vehicles
- Renewable fuels blending[26] in petrol and diesel
- Energy-efficiency improvements in new conventional vehicles

Despite ever increasing road transport, emissions are expected to drop as a consequence of electrification, increased renewable fuels blending, and more efficient conventional vehicles.

4.1 Transport-sector emissions

Developments in total greenhouse gas emissions from the transport sector are presented in Fejl! Henvisningskilde ikke fundet., which shows the historical and projected emissions from 1990-2035, broken down by type of transport. Note that the projection does not explicitly consider any possible long-term effects of the Covid-19 pandemic on the individual transport categories.

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



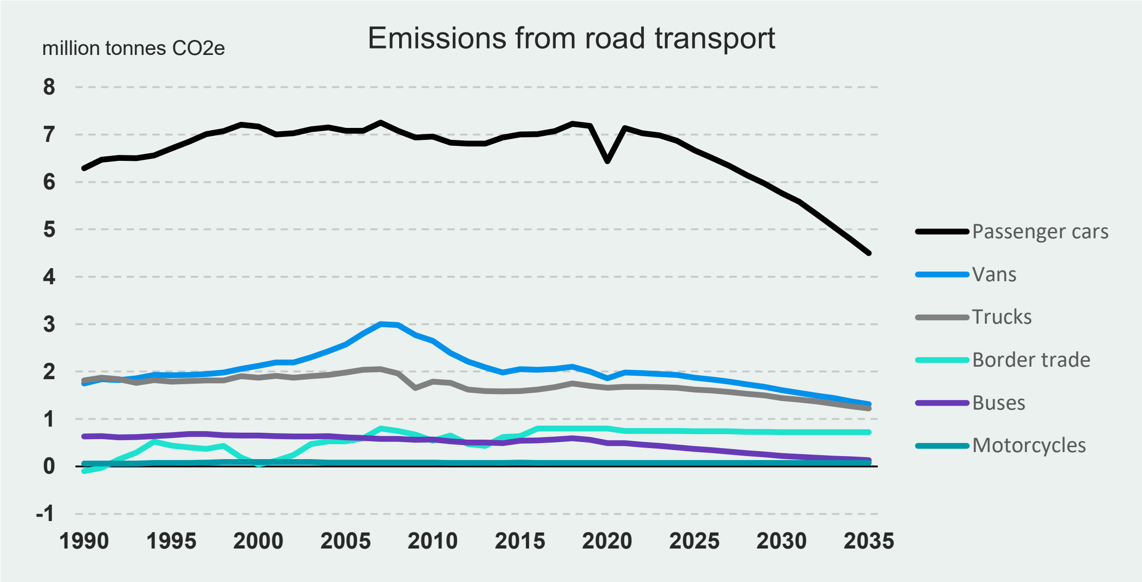
[26] In the memorandum, renewable fuels (fuel produced on the basis of renewable energy sources) is an overall term for biomass-based fuels (e.g., bioethanol and biodiesel) and fuel produced using electrolysis (Power-to-X-technology).

Emissions from road transport

In 2019, road transport emitted 12.3 million tonnes CO_2e, corresponding to 91% of total emissions by the transport sector. Emissions from road transport fell to 11.3 million tonnes CO_2e in 2020, primarily as a consequence of the Covid-19 pandemic. Emissions are expected to increase up to 2021 and then fall gradually up to 2025, when emissions are expected to be at the same level as in 2020. After 2025, emissions start to drop significantly, and in 2030 emissions from road transport are expected to be 9.8 million tonnes CO_2e, corresponding to a drop of 20% compared to 2019. Up to 2035, emissions will fall further to 7.9 million tonnes CO_2e.

Cars account for most of the emissions from road transport at 58% in 2019, 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[27]. Cars are also the category for which the expected decrease in emissions is greatest, both in absolute terms and relative to the size of the emissions.

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



Emissions from road transport depend on activity in the sector, i.e. the demand for transport of passengers and freight on the road network, as well as how this demand is covered in terms of type of vehicle and the composition of the vehicle fleet in terms of technologies and fuels. Demand for road transport is calculated in terms of traffic (number of kilometres travelled) and this is expected to increase in line with general economic growth and an increasing population. Total traffic for all road transport is expected to increase by around 20% from 2020 to 2035. This includes the effects of the "Denmark Forward" 2035 infrastructure plan agreement.

[27]In accordance with the UN IPCC methodology, emissions associated with cross-border trade in fuel are included in the country where the vehicle tanked up. 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.

Despite the continued increase in traffic, a reduction in emissions of greenhouse gases from all vehicle types is expected. The expected decrease in emissions from road transport is largely due to the transition to electric vehicles, increased renewable fuels blending, as well as continued energy-efficiency improvements for conventional vehicles. The phase-in of electric vehicles is expected to be fastest for cars, but sales of electric vans, lorries and busses are also expected to accelerate, particularly after 2030. Trends in the numbers of the different types of vehicles are described in more detail in section 4.2.

Emissions from rail transport, and domestic aviation and shipping
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 expected 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 expected 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 train is expected to be phased out just after 2030.

Emissions from domestic aviation are expected to increase from 0.15 million tonnes CO_2e in 2019, corresponding to 1.1% of total transport sector emissions, to 0.16 million tonnes CO_2e in 2025 and 0.17 million tonnes CO_2e in 2030. From 2030 to 2035, emissions are expected to remain unchanged. The relatively small increase in emissions is due to an expected increase in demand for domestic air travel, which, as all else being equal, will increase consumption of jet fuel. However, this will be counterbalanced in part by expected improvements in energy efficiency. The aviation sector has announced plans for renewable fuels blending up to 2030. However, since these plans are considered financially unfeasible without further regulation of the sector, and since the announced plans are non-binding, they have not been included in the projections. Similarly, account has not been taken for the most recent government announcements regarding green aviation, as no specific initiatives had been implemented before completion of CSO22.

Emissions from domestic shipping are expected to drop slightly from 0.52 million tonnes CO_2e in 2019, corresponding to 3.9% of total transport sector emissions, to 0.51 and 0.50 million tonnes CO_2e, respectively, in 2025 and 2030. The reduction is the result of electrification of a number of ferry services, driven by the funding scheme for the green transition of domestic ferries, among other things. From 2030 to 2035, emissions are expected to remain largely unchanged. With regard to renewable fuels, e.g. ammonia or methanol in shipping, CSO22 does not include the expected phase-in of these alternatives. This is because CSO22 has a frozen-policy approach, and because the alternative fuels are associated with a considerable additional price, including requirements for investment in infrastructure etc.

4.2 Efficiencies and technological development

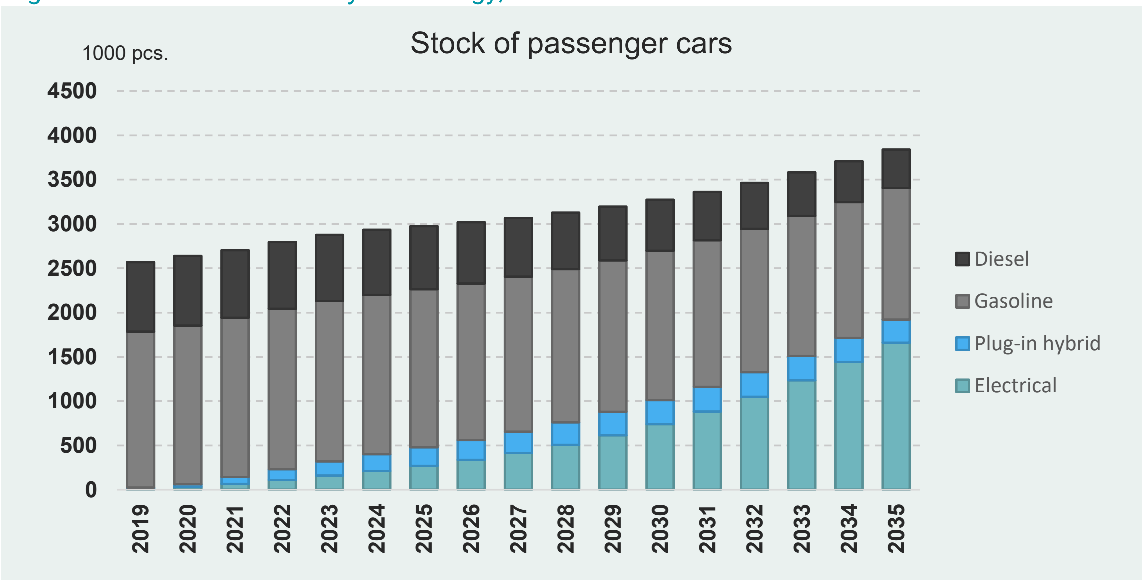
The expected drop in emissions of greenhouse gases from the transport sector are driven by developments in road transport, see the sections below.

More zero- and low-emission vehicles in road transport

This development is driven largely by EU CO_2 regulations on requirements for emissions from the sale of new cars, vans and lorries. The requirements will be tightened regularly up to 2030, and to avoid large fines, vehicle manufacturers are expected to have to accelerate production and sales of zero- and low-emission vehicles, primarily meaning vehicles with electricity and plug-in hybrid technology, as well as improve the fuel efficiency of their conventional petrol and diesel vehicles. The regulations promote technological development, reduce prices for zero- and low-emission vehicles, and increase the range of choices of these. Together with the expected deployment of public charging infrastructure, which will be supported by the green transport pool realisation agreement, these factors mean that zero- and low-emission vehicles will meet the requirements and preferences of more consumers and businesses. Sales of the electric vehicles in particular are expected to increase significantly.

There has been a technological and market development for cars that, combined with a series of relaxations in car taxes, has led to considerable rises in sales of electric cars and plug-in hybrids in recent years. In 2021, electric cars accounted for 13% of new sales and plug-in hybrid cars 22%. Within a few years, sales of electric cars are expected to exceed sales of plug-in hybrid cars, primarily because the phase-out of tax incentives for plug-in hybrid cars will be faster than for electric cars, the range of electric car models available will increase significantly, and the range and recharging infrastructure will also grow. In 2030, about 54% of new cars are expected to be electric cars and just over 6% plug-in hybrid cars. This trend is expected to increase the percentage of electric and plug-in hybrid cars on the road to around 31% in 2030, corresponding to around 1 million electric and plug-in hybrid cars. Of these, around 740,000 will be purely electric cars. In 2035, it is expected that half of all cars in Denmark will be either electric or plug-in hybrids, with a clear majority being purely electric cars. Electric cars are expected to make up 43% of the total number of cars on the road in 2035. This development is illustrated in figure 4.3.

Figure 4.3: Number of cars by technology, 2019-2035



A similar development towards more electric vehicles is expected for the other categories of vehicle. Developments for vans are expected to follow cars relatively closely, although with some delay. In 2021, electric vans accounted for slightly less than 5% of total sales of vans, while plug-in hybrids accounted for around 1%. These percentages are expected to rise to 34% for electric vans and 5% for plug-in hybrids in 2030 and further to 54% and 5%, respectively, in 2035.

Busses and coaches will follow their own trend. A rapid electrification of busses is expected in step with calls for tenders for public contracts, while sales of gas busses will remain relatively low. Expectations with regard to the electrification of tourist coaches, which account for around one-half of the total number of busses, are far lower. In total, around 57% of sales of new busses and coaches in 2030 are expected to be electric, rising to around 72% in 2035.

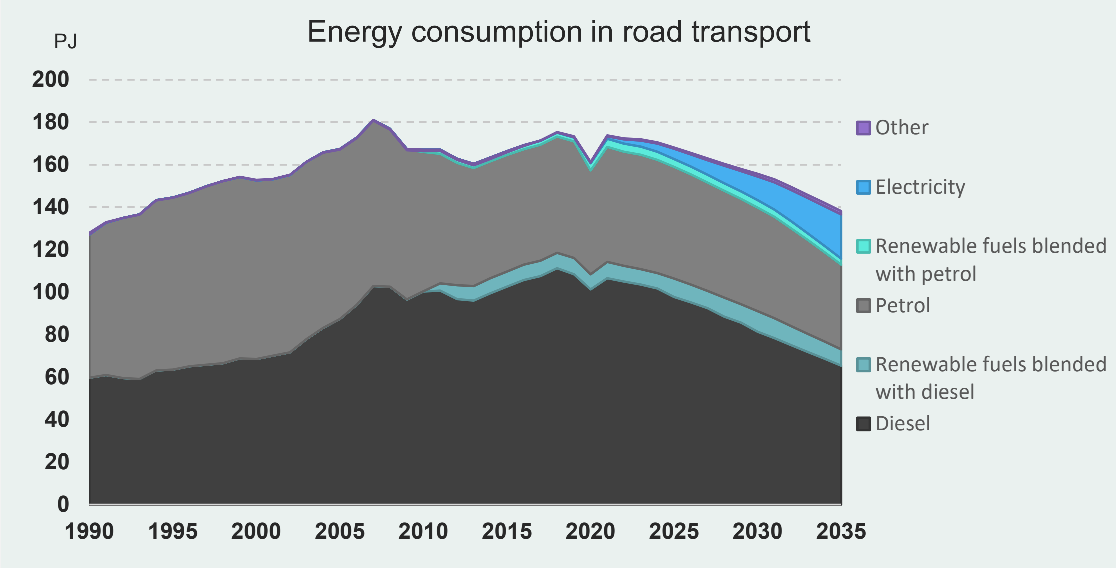
Expectations for electrification possibilities for lorries have until recently been low. However, recent rapid technological developments of batteries, drive lines (engines/transmissions) and infrastructure have increased international expectations that lorries with electric drive lines and batteries will be a realistic solution, for the heavier segments as well. In CSO22, sales of electric lorries are expected to rise to 15% of new sales in 2030 and 35% in 2035.

Despite the relatively progressive electrification of road transport, relatively large sales of conventional vehicles are still expected up to 2035. Thus, purchasers are still expected to have needs and preferences with regard to load capacity, range, performance, etc. that are best met by conventional technologies.

Energy consumption in road transport

The energy consumption of 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 energy consumption following from the growth in demand for transport. The expected electrification is likely to reverse this trend in the projection period and energy consumption will fall up to 2035, as shown in figure 4.4, in which energy consumption is analysed by energy product. Total energy consumption by road transport is expected to drop from about 173 PJ in 2019 to 156 PJ in 2030 and 138 PJ in 2035. Much of the energy consumption will be renewable fuels as a result of a Danish CO_2e-displacement requirement, which will gradually be tightened towards 2030, see sector memorandum 4B.

Figure 4.4: Energy consumption in road transport by energy product



Note: Other includes gas and hydrogen

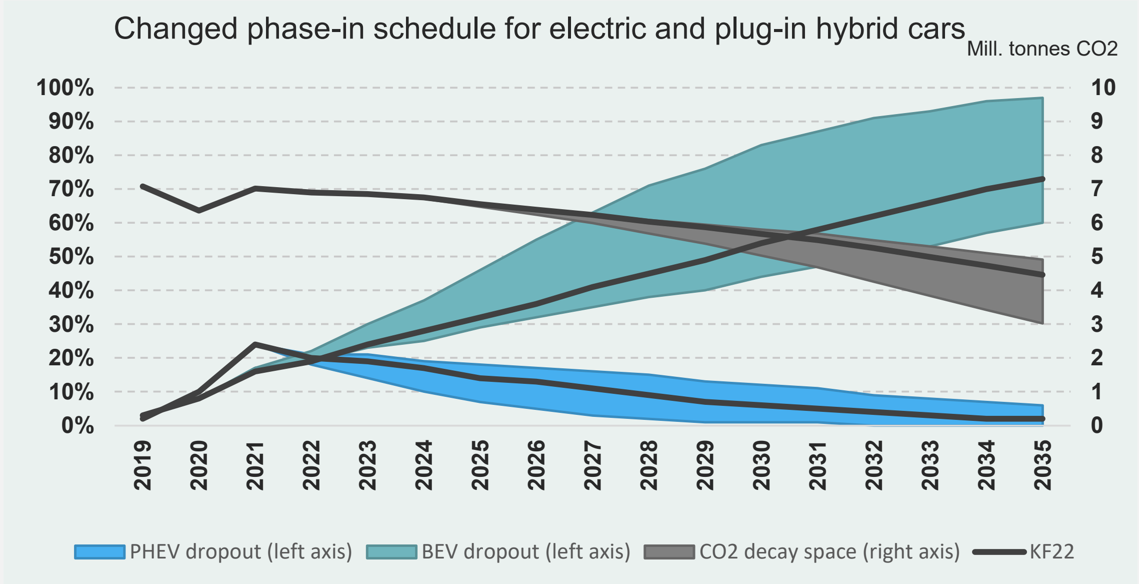
4.3 Uncertainty

The 15-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 developments in opposite directions.

Several sensitivity calculations were carried out for CSO22 for road transport, and these reflect the effect on emissions of changes in selected assumptions significant for the phase-in of zero- and low-emission vehicles, see sector memorandum 4A.

To illustrate the uncertainty associated with the rate of the current transition from conventional to zero- and low-emission cars, two alternative sales scenarios have been calculated for electric and plug-in hybrid cars. Firstly an accelerated scenario in which the time when consumers generally consider electric cars as an alternative to petrol and diesel cars is advanced five years from 2030 to 2025, and a scenario in which the time is correspondingly delayed by five years. The result is illustrated in figure 4.5.

Figure 4.5: The effects of changing the phase-in for electric cars (BEV) and plug-in hybrid cars (PHEV)



If consumer preferences for electric cars increase relative to the assumptions in CSO22, there will be an increase in sales of electric cars, and this will replace sales of other technologies, including plug-in hybrid cars. On the other hand, a scenario in which consumer preferences for electric cars fall will see lower sales of electric cars, and this will benefit sales of other technologies, including plug-in hybrid cars. These alternative scenarios mean that, in 2030 there will be a share of sales of 83% and 1%, respectively, for electric and plug-in hybrid cars in the accelerated scenario, and 43% and 12% in the delayed scenario. Effects on emissions in relation to CSO22 are asymmetric, meaning that accelerated preferences for electric cars lead to a reduction compared with CSO22 of around 0.65 million tonnes CO_2e in 2030 and 1.44 million tonnes CO_2e in 2035, while a delay only gives rise to 0.12 million tonnes CO_2e and 0.45 million tonnes CO_2e more emissions, respectively, in 2030 and 2035.

Changes in traffic are also significant for expected emissions from road transport. Two alternative scenarios to the central CSO22 scenario have been set up, in which traffic grows either quicker, corresponding to the historical growth in the period for 2010-2020, or slower, corresponding to the baseline projection in the National Transport Model (LTM). The difference between the lower and the upper range gives a range of outcomes in emissions of around 0.51 million tonnes CO_2e in 2030 and 0.73 million tonnes CO_2e in 2035.

There is also a difference between the uncertainty linked to the behaviour associated with possibilities to recharge plug-in hybrid cars and drive them on electricity. In CSO22 it is assumed that 50% of use is with electricity. If the percentage of use with electricity is changed to 35% and 65%, emissions will range from 0.2 million tonnes CO_2e in 2030 to 0.16 million tonnes CO_2e in 2035, respectively.

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 in chapter 8, while emissions linked to transport are described in the chapter on transport. Emissions from the service sector are therefore mainly from mains gas used for individual heating, although previously there have also been considerable emissions of F gases.

In 2019 and 2020, the service sector emitted 0.9 and 0.8 million tonnes CO_2e, respectively, corresponding to almost 2% of total Danish emissions. In 2025, 2030 and 2035, the sector is expected to emit 0.6, 0.2 and 0.2 million tonnes CO_2e, respectively, corresponding to around 1% of total Danish emissions in those three years.

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
- Increased renewables share in mains gas, which lowers emissions from the remaining mains gas consumption

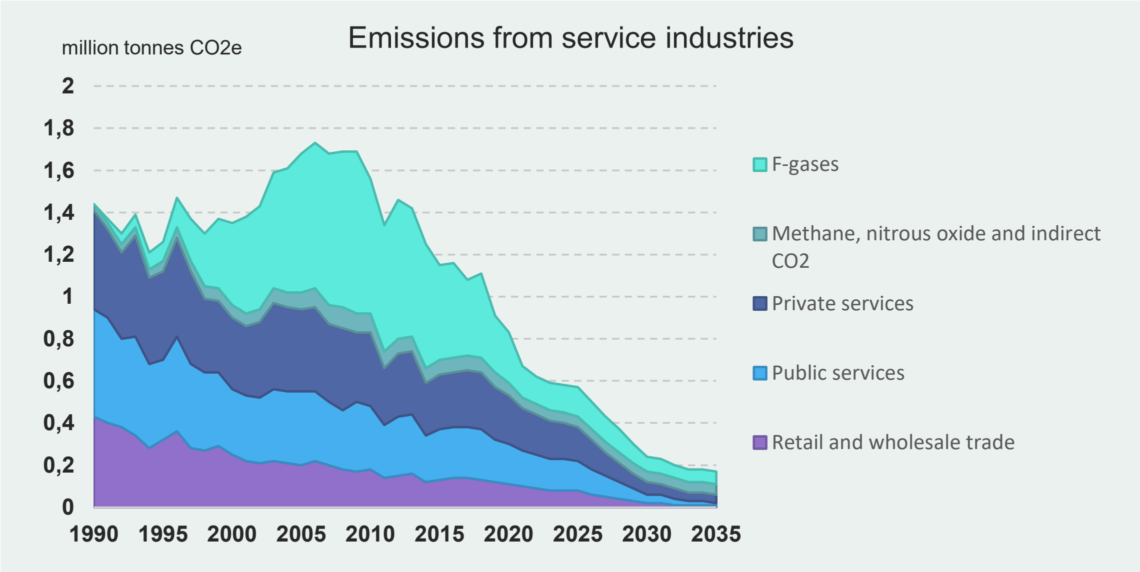
Data centres fall under the private service sector, and are currently expanding considerably. Data centres will lead to significant increases in electricity consumption by the service sector in 2030, but the emissions associated with this are included in chapter 8 on the electricity and district heating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

5.1 Service-sector emissions

Most of the energy consumption is made up of electricity consumption, while emissions by the sector 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 (see chapter 8).

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



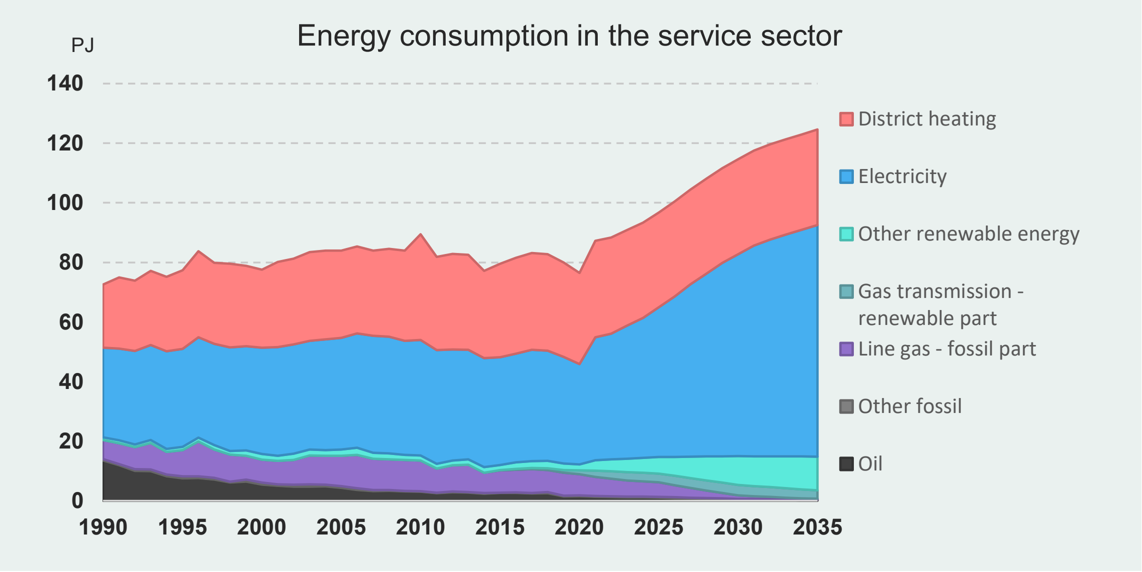
Total emissions by the sector are expected to fall to 0.2 million tonnes CO_2e in 2030 and 2035. This corresponds to a decrease of 74% and 81% respectively compared with 2019. Up to today, reductions have been driven in particular by the shift from oil-based heating to district heating, while expected 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 2020, emissions from mains gas amounted to two-thirds of the sector's total emissions, but this percentage is expected to drop to around 30% by 2030 and right down to 6% in 2035 as a result of the shift from gas-fired boilers to heat pumps, and in light of the significant increase in the renewables share in mains gas.

In 2025 more than one-half of the emissions stemmed from space heating, with by far the majority coming from mains gas. The remaining emissions in 2030 are more evenly distributed between gas-fired boilers for space heating, fossil energy consumption and waste incineration for medium-temperature process heat, indirect CO_2 from mobile sources and F gases. In 2035, emissions will primarily be from waste incineration for medium-temperature process heat, indirect CO_2 and F gases. Medium-temperature process heat is used at hospitals, laundries and in restaurants, for example, while indirect CO_2 emissions from mobile sources are linked to incomplete combustion when using petrol in power saws and lawn mowers, for example. F gases come especially from cold-storage installations in the sector.

5.2 Efficiencies and technology changes

Even though the service sector does not account for more than 2% of total emissions, the sector uses 13% of total Danish final energy consumption, increasing to 20% in 2035. As can be seen in figure 5.2, final energy consumption in the service sector is expected to increase from 80 PJ in 2019 to 125 PJ in 2035. The increase in energy consumption by the service sector is mainly due to establishment of data centres. In 2019, just under 1 PJ of electricity was consumed by data centres in Denmark, but this is expected to increase to 27 PJ in 2030 and to 35 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. In general, increasing electricity consumption for heat pumps is expected. In 2019, electricity accounted for 45% of the sector's final energy consumption. This figure will increase to 63% in 2035. This means that, with the current projections, 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 2020 and is expected to drop to 5 PJ in 2030 and 3 PJ in 2035. The reduction in gas consumption is primarily due to conversion from gas-fired boilers to heat pumps. Emissions attributable to this will fall further as a consequence of the significant increase in the renewables share in mains gas. By converting from gas heating, for example, the renewables share in the remaining mains gas consumption will rise, and this will lead to further CO_2e reductions.

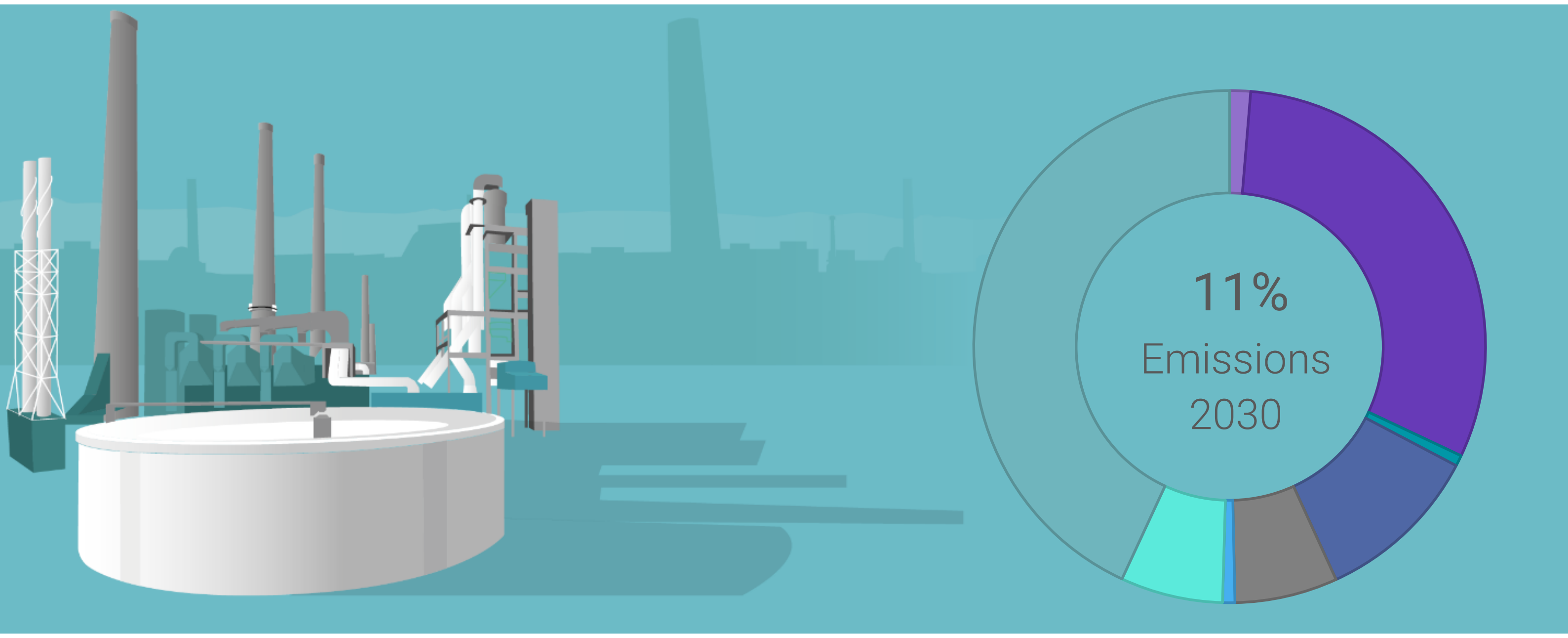
5.3 Uncertainty

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.[28] This does not, however, affect emissions from the service sector, as the emissions from electricity production are under the electricity and district heating sector.

Emissions from the sector are relatively limited, but because part of the explanation for this is the increased share of renewables in mains gas, changes in the sector's gas consumption will have derived impacts on total emissions that exceed the impact on the sector's own emissions.

The projection of indirect CO_2, which comes in particular from the use of petrol, has been drawn up on the basis of the historical use of petrol, and this may mean that emissions are over-estimated.

[28]Read more about the assumptions used for the projection of electricity consumption in CSO22 memorandum on assumptions 6A 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.

In both 2019 and 2020, the manufacturing and building and construction sector emitted 5.1 million tonnes CO_2e, corresponding to around 11%, respectively, of total Danish emissions. In 2025, 2030 and 2035, the industries are expected to emit 4.7, 3.7 and 3.1 million tonnes CO_2e, respectively, corresponding to just over 11%, 11% and just over 10%, respectively, of total Danish emissions. The expected changes in emissions from these industries are due in particular to the following expectations regarding future energy consumption:

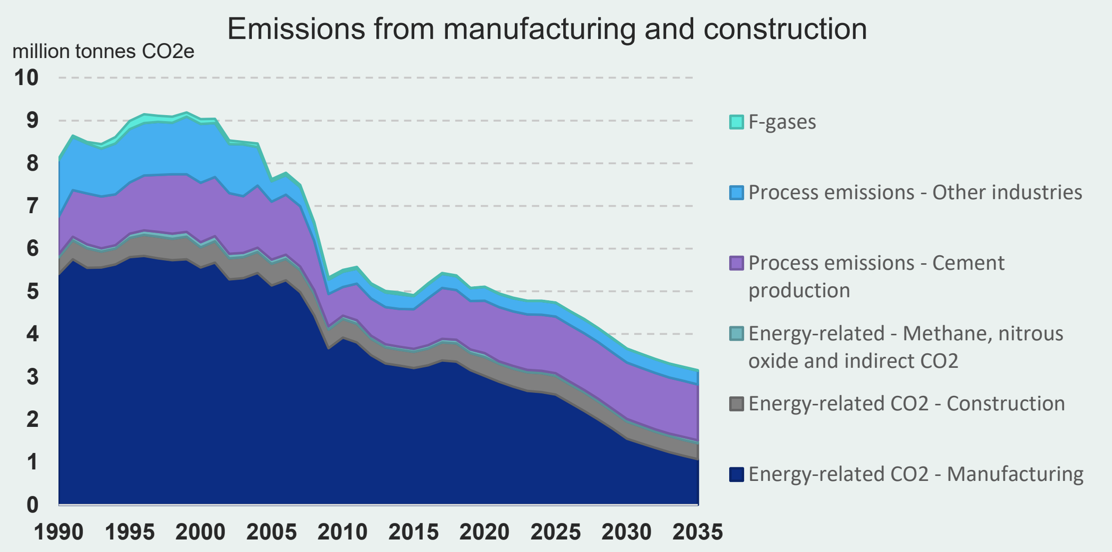
- More widespread electrification and higher energy efficiency, including more use of heat pumps for internal exploitation of surplus heat
- Increased renewables share in mains gas

6.1 Emissions by the manufacturing and building and construction sector

Emissions from manufacturing industries are characterised as having a large share of process emissions compared with the other sectors. *Process emissions* are emissions that occur as the product of a chemical process in production. 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.[29]

Total emissions from the manufacturing and building and construction sector for the period 1990-2035 are illustrated in figure 1. Emissions include energy-related emissions, process emissions and a small amount of F gases. Total emissions fell in the period from 1990 up to 2020 from 8.1 to 5.1 million tonnes CO_2e, corresponding a fall of 37%. Up to 2025 and 2030, the sector is expected to reduce emissions by a further 0.4 and 1.4 million tonnes CO_2e, respectively, compared with today and in 2035 emissions are expected to be reduced to just over 3.1 million tonnes CO_2e.

Figure 6.1: Emissions by the manufacturing and building and construction sector



Note: F gases are a group of potent greenhouse gases used as refrigerants in cold-storage installations and air-conditioning systems, among other things. F gases are described in more detail in memorandum on assumptions 9C.

Since 1990, there has been a drop in all three types of emissions, but energy-related emissions in particular have contributed to the total reductions. Up to 2025 and 2030, energy-related emissions are expected to continue to fall, while process-related emissions, in contrast, are expected to increase slightly. Therefore, this shifts the distribution between energy-related and process-related emissions, so that process-related emissions from the sector in 2030 will amount to 45% compared with 30% today, and in 2035, process-related emissions are expected to amount to more than

[29]Emissions from consumption of electricity and district heating as well as from refining are not dealt with in this chapter, as they are included in the calculation of emissions from the utilities sector (see chapter 8) and the calculation of emissions from the production of oil, gas and renewable fuels (see chapter 7).

one-half of the emissions from the manufacturing and building and construction sector.

6.2 Efficiencies and technology changes

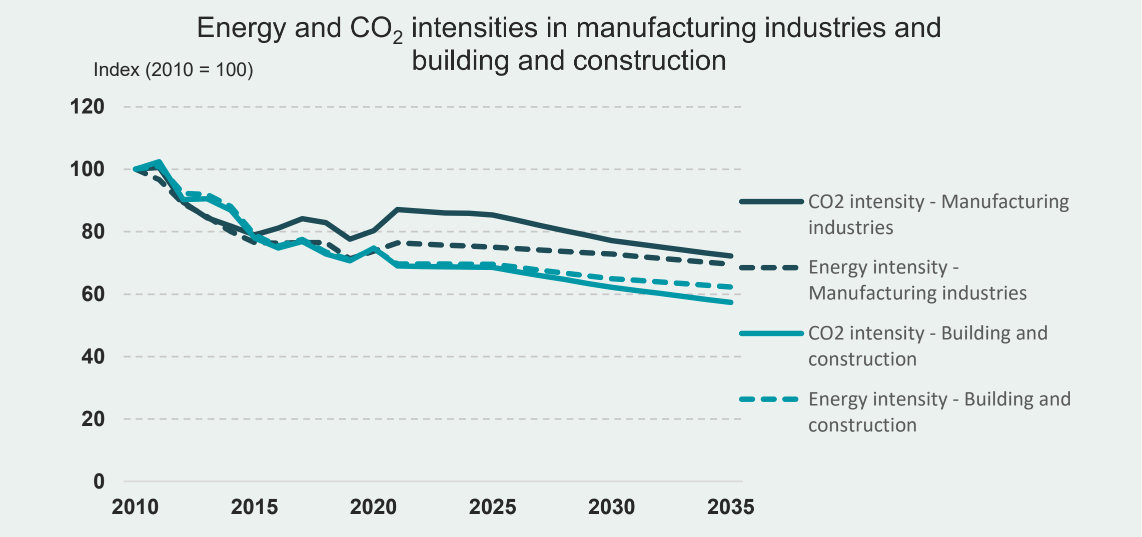
Reductions in emissions have occurred and will continue to occur, despite expectations of growth in both the manufacturing industries and in the building and construction industries. Amongst other things, the falling emissions can be explained by energy-efficiency improvements and, with respect to the historical trend, structural shifts towards less energy-intensive industries. Expected increased cement production in the future pulls in the opposite direction, and this is the decisive factor for continued high process emissions, see above.

Energy intensity and CO_2 intensity

The CO_2 intensity of the business sector is a key indicator for CO_2 emissions per economic unit produced. CO_2 intensity will be lower if industry becomes more energy efficient or replaces fossil fuels with renewables. Structural shifts in the business sector can also affect CO_2 intensity.

As can be seen from figure 6.2, both CO_2 intensities and energy intensities in manufacturing industries and in building and construction industries have been decreasing since 2010, and this trend is expected to continue up to 2030, as well as onwards up to 2035, although for energy intensities only slightly. CO_2 intensity falls faster than energy intensity because CO_2 emissions reductions primarily take place as a result of a shift in fuel away from fossil fuels and towards increased electrification, and as a result of an increased renewables share in mains gas.

Figure 6.2: Energy and CO_2 intensities in manufacturing industries and building and construction industries.



Note: Energy intensity has been calculated as energy consumption in relation to production, and CO_2 intensity has been calculated as CO_2 emissions relative to production.

An expected increased internal exploitation of surplus heat through the use of heat pumps in manufacturing industries will also help reduce CO_2 intensity in the future. Surplus heat is expected to be used for both space heating and medium-temperature process heat, and it will replace a large amount of mains gas and to a lesser extent solid fuels, and thereby exploitation of surplus heat will help to reduce CO_2e emissions from manufacturing industries.

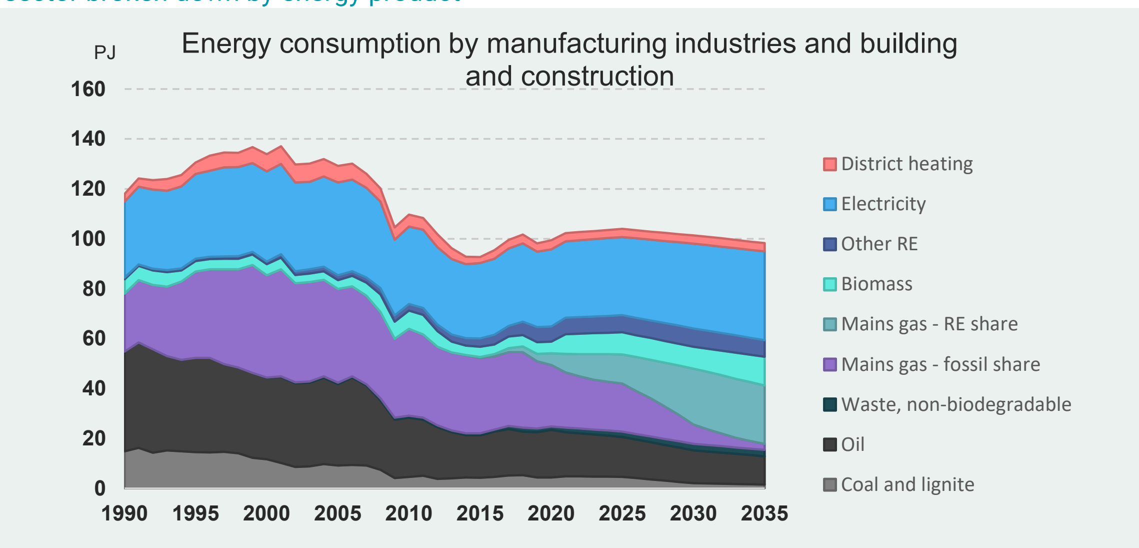
Figure 6.2 shows CO_2 and energy intensities with indexed figures. In terms of observed emissions, building and construction industries use considerably less energy and emit less CO_2 per unit produced than manufacturing industries. Manufacturing industries had energy and CO_2e intensities of 0.11 PJ per DKK billion and 6.7 kt CO_2e per DKK billion in 2020, respectively, while building and construction industries had corresponding intensities of 0.02 PJ per DKK billion and 1.3 kt CO_2e per DKK billion, respectively. Building and construction industries therefore had significantly less energy consumption and CO_2e emissions per unit produced than manufacturing industries.

Energy consumption

A relatively large share of energy-related emissions by manufacturing industries are linked to a number of specific production processes that require high temperatures (above 150° C) that are achieved through direct fossil-fuel firing. Therefore, historically there has been a large percentage of fossil fuels in final energy consumption by the manufacturing and building and construction sector, as shown in figure 6.3.

The percentage of fossil fuels is falling, however. In 1990, 66% of energy consumption by the manufacturing and building and construction sector comprised fossil fuels, while today this is 50%. In 2025 it is expected to drop to 40% and in 2030 to 25%. Looking further to 2035, it is expected to drop to 18%.

Figure 6.3: Final energy consumption by the manufacturing and building and construction sector broken down by energy product



Before 2030 the amount of renewable energy in the manufacturing and building construction sector is expected to exceed the amount of fossil energy (looking at the primary fuels and not electricity and district heating). The drop in use of fossil fuels primarily reflects an expected considerable increase in the share of renewable energy in mains gas, but also an increase in the use of waste (including biodegradable waste), which will displace coal and pet coke in cement production.

Reductions in the cement industry are particularly challenging because of the high energy consumption in high-temperature processes. High-temperature processes usually require direct firing with fuel or have to be at temperatures where electrification, for example, is often difficult in existing production plants. Electricity can be used for high-temperature processes in some situations, but it will often require total replacement/rebuilding of the production plant. For the rest of the manufacturing and building and construction sector, on the other hand, electrification of the primary medium-temperature processes and space heating is possible with heat pumps.

From and including 2024, gas consumption in the food industry is expected to increase as a consequence of a new gas connection to the sugar factories on Lolland. Furthermore, from and including 2022 consumption of mains gas is expected in the cement industry following the newly established gas connection to Aalborg Portland. It is expected that the cement industry will have gas consumption of 2.7 PJ, out of total energy consumption of 14.6 PJ in 2030.

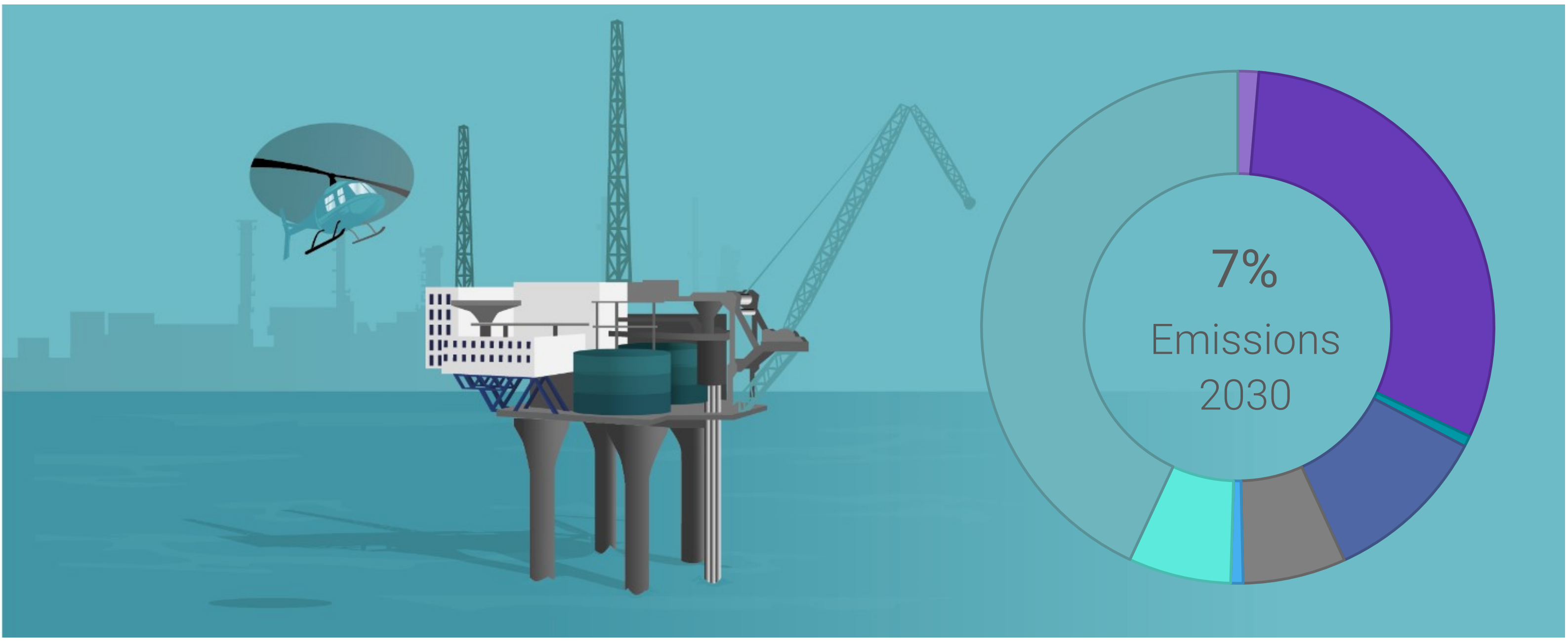
As described in chapters 3 and 5, the higher renewable energy share in mains gas and the consequential lower emissions in the manufacturing and building and construction sector are due to developments in the composition of mains gas (see sector memorandum 7B).

Furthermore, figure 6.3 shows that total final energy consumption by the manufacturing and building and construction sector will be largely stable over the coming years. A slight increase is expected up to 2025, after which it will fall slightly again. In 2035, total energy consumption in the manufacturing and building and construction sector is expected to be around 1 PJ lower than at present. The relatively stable energy consumption is despite growth in the sector, see figure 3, which will be counteracted by investments in energy savings and conversion to more energy-efficient technologies.

6.3 Uncertainty

Uncertainty in emissions from the manufacturing and building and construction sector is associated with activity levels for both manufacturing industries and building and construction industries. For the cement, glass and tile industries specifically there are also uncertainties associated with fuel consumption in production, and the finished cement product.

Great uncertainty is linked to emissions from cement production. For example, this uncertainty concerns the share of alternative fuels, average shares of cement clinker in the finished cement product, and changes in activity levels, and these uncertainties are presented as a sensitivity analysis compared to the basic scenario in sector memorandum 6A.



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 Power-to-X (PtX). The sector emitted 2.4 and 1.9 million tonnes CO_2e, respectively, in 2019 and 2020, corresponding to 5% and 4%, respectively, of total Danish emissions. In 2025, 2030 and 2035, the sector is expected to emit 2.4, 2.3 and 2.1 million tonnes CO_2e, respectively, corresponding to 6%, 7% and 7% of total Danish emissions.

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, up to 2027
- The energy consumption of refineries is assumed to remain unchanged and emissions are therefore expected to be constant.

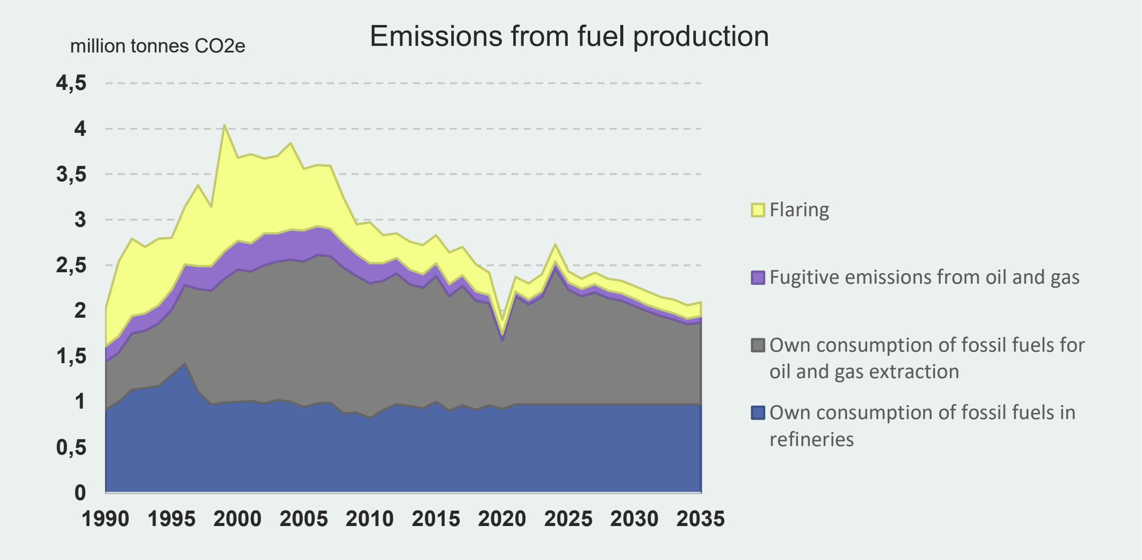
Furthermore, developments in electricity consumption by the sector are also influenced by biogas production deployment (in the form of electricity consumption for biogas upgrading) and PtX deployment (in the form of electricity consumption for electrolysis). Emissions associated with electricity production are included under the electricity and district heating sector in chapter 8. The effect on the renewables share in mains gas is included in 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. 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. Emissions associated with methane leakages from biogas production are included in waste sector emissions in chapter 9, while emissions associated with consumption of natural gas or other fossil fuels to meet energy consumption in biogas production are included under other sectors.

Total emissions by the sector for the period 1990-2035 are 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 and is expected to amount to around 95% of emissions from the sector by 2030. The reduction in emissions in 2020-2022 is due to redevelopment of the drilling rig in the Tyra field, which is therefore out of commission. The increased emissions from 2023 to 2027 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. After 2027, extraction of oil and gas will fall due to aging oil fields.

Figure 7.1: Emissions from fuel production broken down by own consumption of fossil fuels at refineries, as well as oil and gas extraction, flaring and volatile emissions



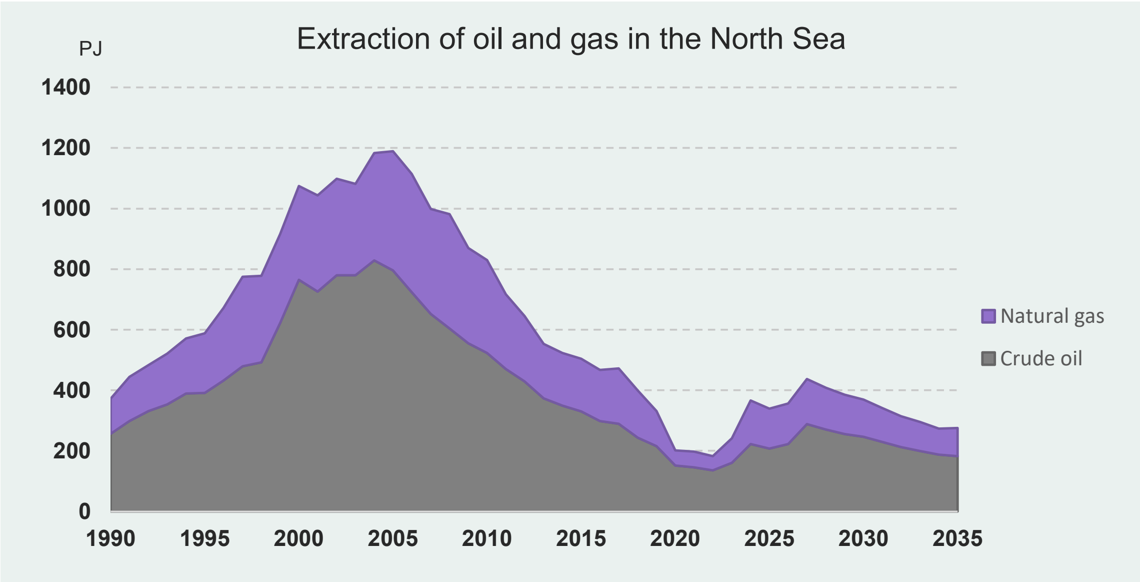
Extraction of oil and gas

Emissions associated with oil and gas extraction are linked to the activity level in the sector. Emissions from oil and gas extraction are expected to be around 1.2 million tonnes CO_2 in 2030, falling to around 1.0 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 illustrates trends 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 in the mid-2000s, after which a downward trend is seen.

Extraction of oil and gas is expected to increase up to 2027, amongst other things due to the redevelopment of installations in the Tyra field and commissioning of a number of other, smaller projects. After 2027, extraction is expected to fall due to ageing fields. Expected extraction of oil and gas from the North Sea in 2035 is 80 PJ for gas and 180 PJ for oil.

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 2021-2023 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 (except in 2027).

Figure 7.2: Oil and gas extraction in the North Sea



Refineries

Emissions from refineries are expected to be around 1.0 million tonnes CO_2 in 2030 and in 2035. In CSO22, the energy consumption of refineries is assumed to remain constant up to 2035, see memorandum on assumptions 7B. In the most recent historical period, activity has increased slightly and this trend has been countered by continual efficiency improvements. Emissions from refineries are closely linked to energy consumption and are also expected to remain constant throughout the period, as illustrated in figure 7.1. In CSO22, the energy consumption of refineries is assumed to remain constant, and for this reason the figures do not include any modelling of the future activity of refineries and any effect that the CO_2 allowance price could have on this activity. A higher allowance price could encourage additional efficiency improvements and/or replacement of some of the refinery gas with hydrogen, for example, which could have an effect on total emissions, although this effect has not been included in emissions by refineries in this report.[30] The extra partial effect on emissions from refineries from an increasing CO_2 allowance price is assessed to be around 0.08 million tonnes CO_2, see chapter 2.

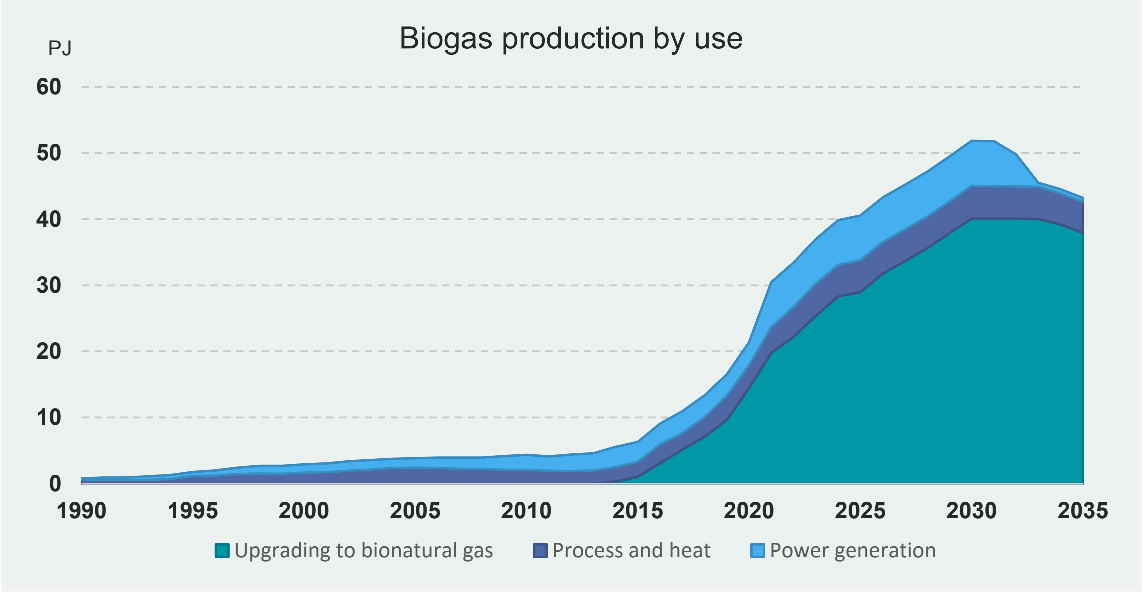
Production of biogas and biofuels

Biogas is produced at a number of different installations in Denmark, with the majority of the production taking place at agricultural installations (see CSO22 memorandum on assumptions 7C). Production of biogas is illustrated in figure 7.3 for the period 1990 to 2035. Production of biogas for upgrading to biomethane grew significantly during the 2010s and this growth in biogas production is expected to continue up to 2030, when production is expected to peak at just over 50 PJ. In the period 2030 to 2035, it is expected that biogas production for electricity production will fall, as the majority of electricity-generating plants have only been pledged financial support up to 2032.

The increased production of biogas and upgraded biogas is driven by subsidy schemes for biogas production, and the size of the production in CSO22 therefore depends on the demand. Changes in demand for mains gas will therefore impact fully in the part of mains gas consumption that remains fossil-based and will therefore change the renewables share of mains gas (see also sector memorandum 7B).

[30] The extra partial effect on emissions by refineries has, however, been deducted from the 2030 emissions gap (see table 2.1).

Figure 7.3: Production of biogas by use



In addition to biogas, Demark also has production of liquid biofuels in the form of biodiesel. Emissions associated with this production are included in the climate accounts of other sectors, and there is no data basis to identify those explicitly in CSO22.

PtX

In CSO22, 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 CSO22. CSO22 assumes electrolysis capacity deployment up to 254 MW from 2024, after which capacity will remain constant up to 2035. Hydrogen production by electrolysis is expected to be at around 2.0 PJ in 2030 and 2.3 PJ in 2035. Electricity consumption for electrolysis is expected be around 3.0 PJ in 2030 and 3.4 PJ in 2035.

The agreement to develop and promote hydrogen and green fuels (the PtX strategy), agreed by the government and several parliamentary parties on 15 March 2022, has not been included in CSO22. This is because the agreement was concluded after the cut-off date (1 January 2022) for inclusion of measures in CSO22.[31] Any direct and indirect effects of the agreement will be included in future climate status and outlook reports.

7.2 Uncertainty

Oil and gas extraction

It is uncertain whether a higher CO_2 allowance price can sufficiently incentivise technical improvements in the form of energy-efficiency improvements, for example,

[31] See the underlying CSO22 memorandum on assumptions 2C for further explanation of the principles behind the frozen-policy approach in Denmark's climate status and outlook reports.

leading to lower emissions. Higher prices of fossil fuels could 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, but over the past twenty years there have only been slight fluctuations in energy consumption. However, the figures do not include any modelling of the future activity of refineries but assumes a constant energy consumption in the projection period. It is uncertain whether a higher CO_2 allowance price can give rise to a reduction in emissions through efficiency improvements measures and/or replacing some of the refinery gas with hydrogen, for example. Energy-efficiency improvements can lead to lower emissions, while it is uncertain whether replacing refinery gas with hydrogen will lead to lower emissions, because it is uncertain whether refinery gas will displace fossil fuels elsewhere.

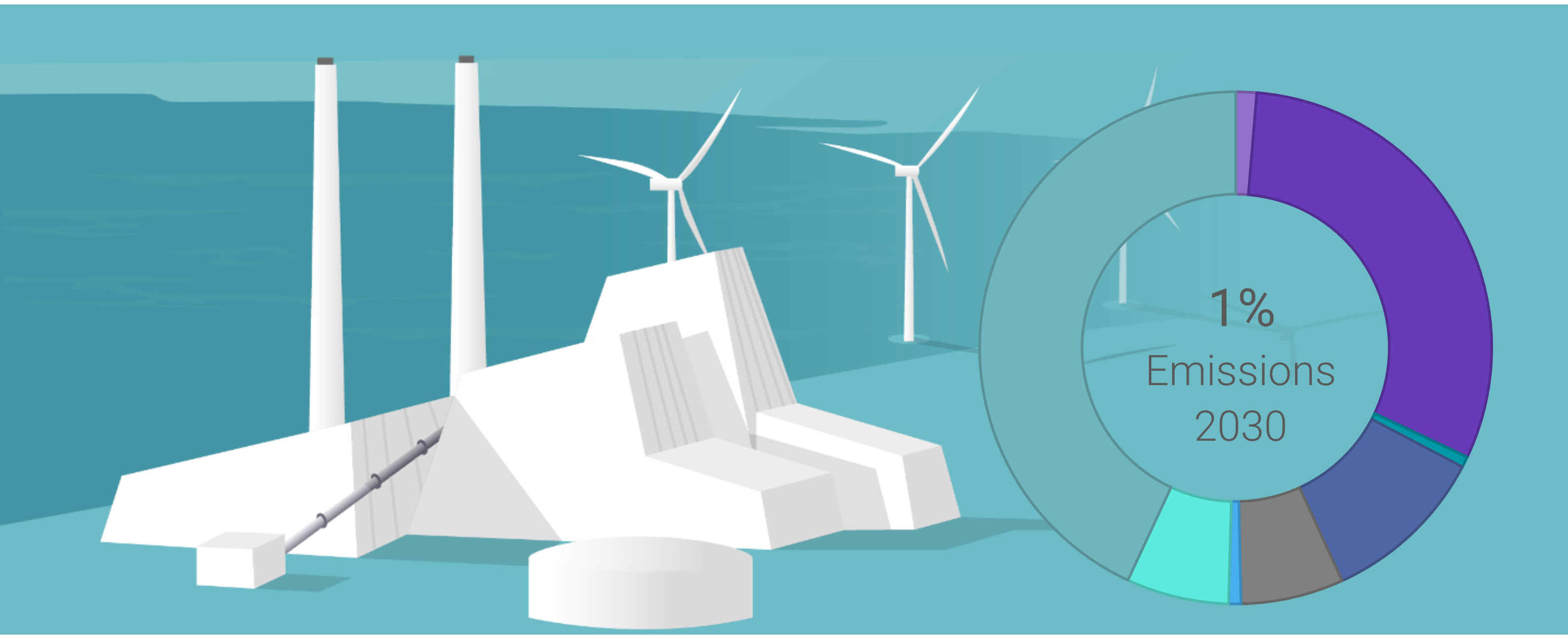
Biogas production

Because the amount of upgraded biogas plays an important role for emissions in other gas-consuming sectors, a sensitivity calculation has been performed for the impact on the renewables share in mains gas of a change in the amount of upgraded biogas of ± 3 PJ in 2030, increasing to ± 5 PJ in 2035. In the low estimate, the renewables share is 69% and 80%, respectively, in 2030 and 2035, while in the high estimate the renewables share is 79% and 103%, respectively, in 2030 and 2035[32]. For comparison, the basic scenario shows a renewables share in mains gas at 75% in 2030 and 92% in 2035 (see table 2.2).

PtX

A sensitivity calculation has been made of hydrogen production by electrolysis and associated electricity consumption, based on the assumption that the planned tendering procedure for PtX and EU approval for the IPCEI projects in combination lead to an electrolysis capacity of 600 MW rather than the 200 MW assumed to come about from the PtX tendering procedure in the basic scenario. The sensitivity analysis assumes a total electrolysis capacity of 654 MW electrolysis from 2025 and onwards. The sensitivity calculation shows hydrogen production of around 7.2 PJ in 2030 and associated electricity consumption of around 10.9 PJ assuming the modelled number of full load hours.

[32] A renewables share above 100% indicates net exports



8 Electricity and district heating

In CSO22, 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[33]. 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 2020, the electricity and district heating sector (excluding waste incineration) emitted about 3.9 million tonnes CO_2e, corresponding to 9% of total Danish emissions. In 2025, 2030 and 2035, the sector is expected to emit 1.3, 0.3 and 0.15 million tonnes CO_2e, respectively, corresponding to 3%, 0.8% and 0.5%, respectively, of total Danish emissions in the years in question. The expected changes in sector emissions are due to several factors, including:

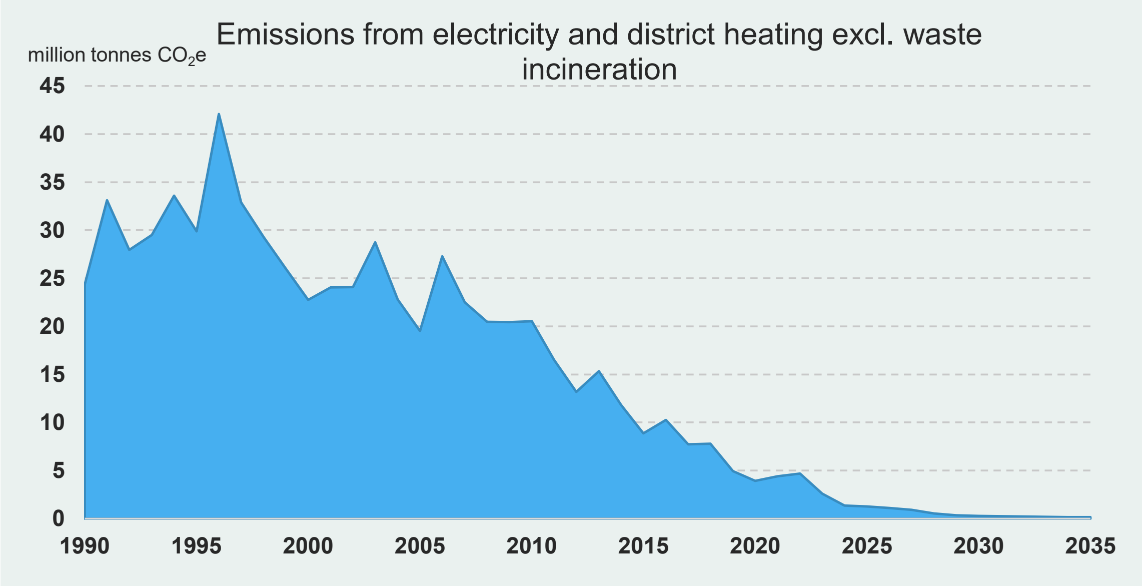
- phase-out of the last coal-fired CHP plants,
- continued deployment of wind power and photovoltaic modules,
- significant further deployment of heat pumps to produce district heating, and
- reduction in CHP production based on mains gas.

[33] Waste incineration plants also supply electricity and district heating, but in CSO22 they 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 CSO22, energy consumption and associated greenhouse gas emissions from autoproducers are stated under the sectors to which the producers belong.

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

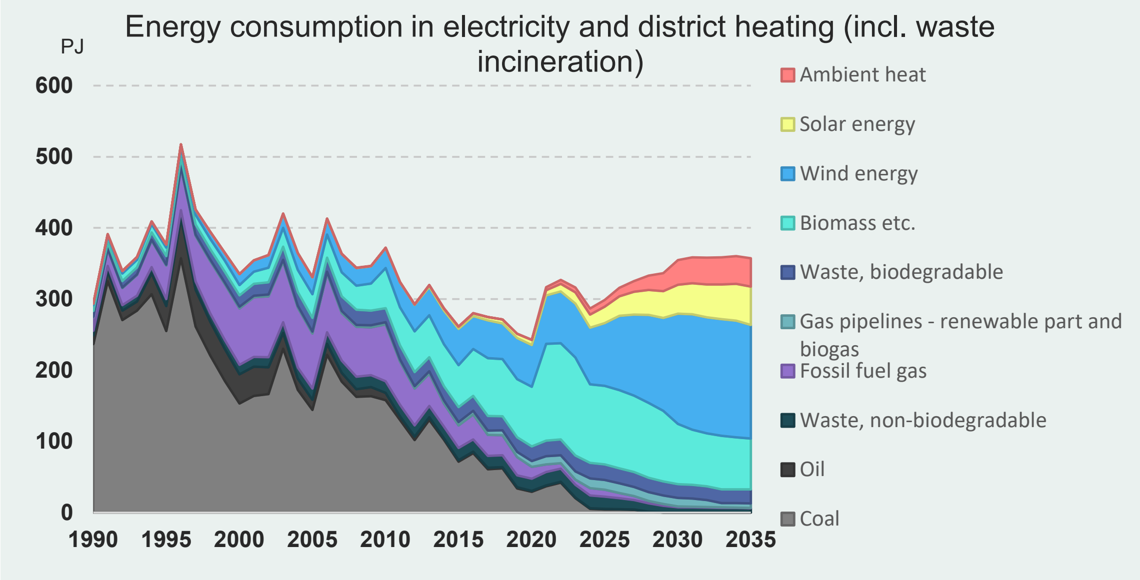


As figure 8.1 shows, from 1990 to today the electricity and district heating sector moved from having large greenhouse gas emissions to having a significantly smaller climate footprint. This trend is expected to continue over the projection period up to 2035, and emissions from the sector are expected to be 0.3 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. For the same reason, electricity consumption is expected to increase significantly in the projection period up to 2035.

8.2 Efficiencies, changes of technology and energy consumption

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 photovoltaic modules.

Figure 8.2: Energy consumption in the electricity and district heating sector, by type of energy[34] (PJ).



Overall, consumption of fossil fuels for electricity and district heating production is expected to fall by 50%, 87% and 90%, respectively, in 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[35], 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 this will be amplified by the renewables share of mains gas increasing further up to 2030.

In the beginning of the projection period, a significant increase in fossil fuel prices (see memorandum on assumptions 3A) will lead to a higher share of electricity and district heating production being based on coal, mains gas, and, in particular, biomass. This is because rising fuel prices will raise the price of electricity, which will make it beneficial for Danish electricity producers to increase their thermal electricity production.

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

[34] Although, in CSO22, waste incineration is not included in the calculation of greenhouse gas emissions from the electricity and district heating sector, waste incineration is included in the calculation of energy consumption by the sector, because waste incineration plays an important role in the district heating sector.
[35] The agreement under the 2022 Finance Act for an additional 2GW offshore wind before 2030 will further expedite this.

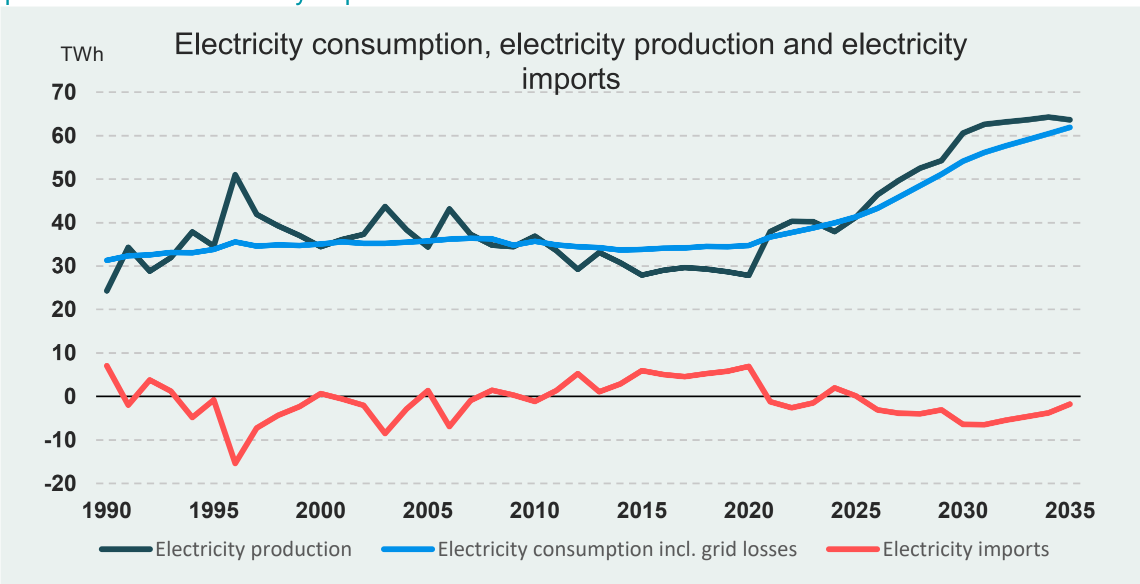
(Power-to-X). However, this requires that increasing electricity consumption is accompanied by continued deployment of more renewable energy.

In a long-term climate perspective, the sector faces the challenge of how and to what extent electricity and district heating can be supplied in the quantities needed, and what resources, financial and natural, are needed in the form of land, raw materials, etc.

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.



Under the assumptions made, including assumptions about the energy islands[36], domestic electricity production is expected to exceed domestic electricity consumption in most years up to 2035. However, the results are associated with significant uncertainty linked to several factors, both on the production side, e.g. on the launch of future offshore wind farms and solar PV projects, and with respect to demand, including developments in electricity consumption by large data centres. 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.

[36] The energy islands are not included in the CSO22 basic scenario, as described in CSO22 memorandum on assumptions 8A on offshore wind.

The energy islands are expected to have a considerable and positive influence on the Danish electricity balance. When the energy islands have been realised, Denmark is expected to have a large surplus of green electricity to exploit, directly or indirectly, in electrification of other sectors or to export to countries neighbouring Denmark, and it is expected this will displace fossil-based electricity production in these countries with a consequential positive climate impact.

Fluctuating electricity production and flexible electricity consumption

In a future where intermittent energy sources will come 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 likewise be a challenge to match supply and demand at all times in an interplay with all sectors involved, including through increased demand-side flexibility.

CO22 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. This share is expected to be reduced to around 55% in 2030 and around 50% in 2035. The mix in electricity demand will therefore be significantly different up to 2030 and 2035. Similarly, electricity demand for electrolysis and partly also for district heating supply can respond more flexibly to fluctuating, wind-based and solar-based electricity production.

8.3 Uncertainty

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. Thus, for example, in 2030 variations will be in the range of -0.1 million tonnes CO_2e to +0.2 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.

CSO22 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 energy islands are included in projections.

Alternative scenario with energy islands

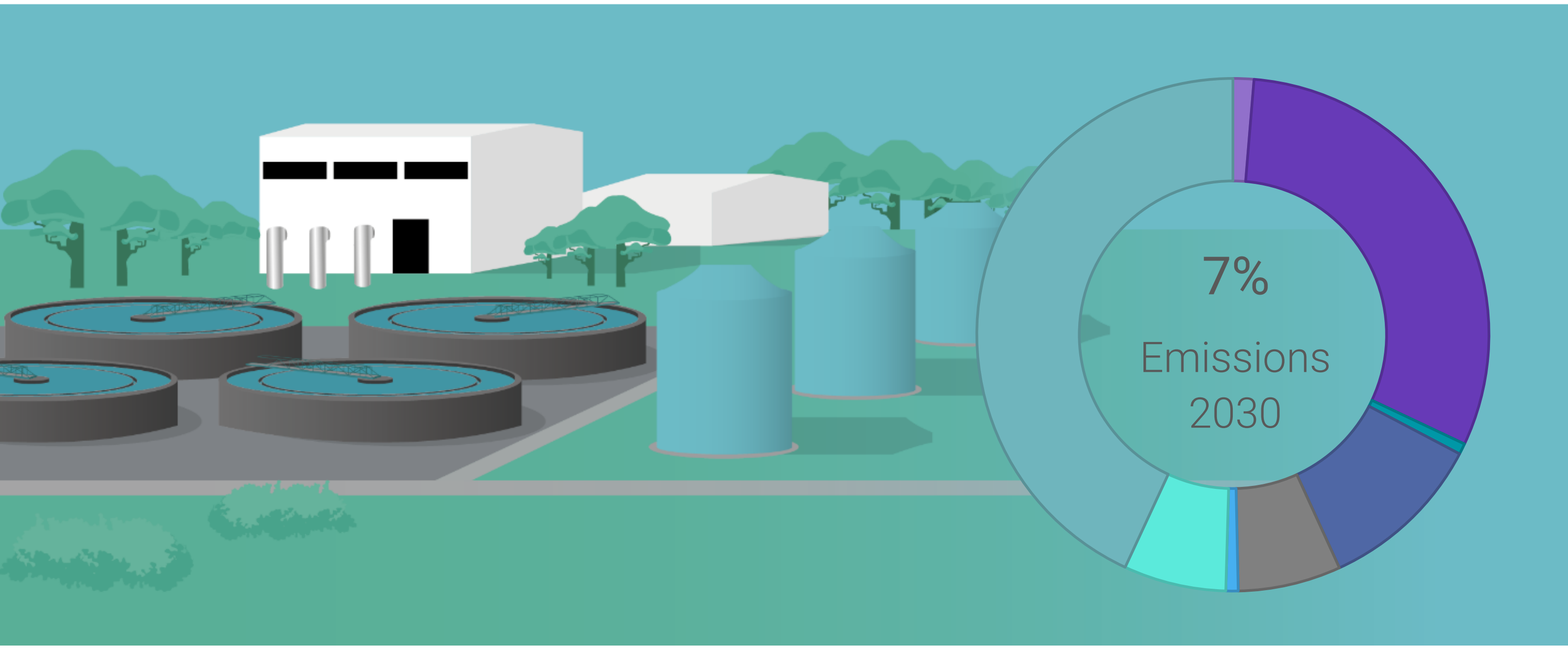
The energy islands are not included in the CSO22 basic scenario. The system and climate consequences of the energy islands for the Danish electricity and district heating sector have therefore been examined through a partial sensitivity calculation, which assumes that the energy island off Bornholm will be connected to the grid in 2029-2030 and the energy island in the North Sea will be connected to the grid in 2032-2033, while domestic electricity consumption will remain unchanged[37].

In the sensitivity calculation including the energy islands, the renewables share in electricity consumption in 2030 increases from 109% to 123%, and in 2035 from 102% to 138%. A renewables share in electricity consumption of more than 100% means that, with the energy islands, Denmark is expected to have a large surplus of green electricity that can be utilised 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 calculation also shows that, on their own, the energy islands have only very little direct significance for Danish emissions of greenhouse gases[38]. The reason for the small effect on Danish emissions is that there is already very little fossil-based electricity production in Denmark. However, the energy islands 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 energy islands will open for the opportunities to meet any new domestic electricity demand, for example for the additional production of green fuels (Power-to-X), which can displace fossil fuels in other sectors.

[37] CSO22 sector memorandum 8A contains a description of the assumptions behind the partial alternative scenario with energy islands.

[38] The effect on Danish CO_2 emissions towards the end of the projection period is assessed to be in the interval +0.01 million tonnes to - 0.02 million tonnes, see CSO22 sector memorandum 8A.



9 Waste (including waste incineration)

In CSO22, the waste sector includes treating waste and wastewater from households, the service sector and industries; composting garden and parkland waste; as well as methane leakage from biogas plants[39]. In 2019, the sector emitted about 2.9 million tonnes CO_2e, corresponding to around 6% of total Danish emissions. In 2025, 2030 and 2035, the sector is expected to emit 3.2, 2.3 and 2.0 million tonnes CO_2e, corresponding to 8%, 7% and 7%, respectively, of total Danish emissions. In general, these emissions depend on the volumes and types of waste in question, including how the waste is treated. The expected changes in sector emissions are due, in particular, to the following factors:

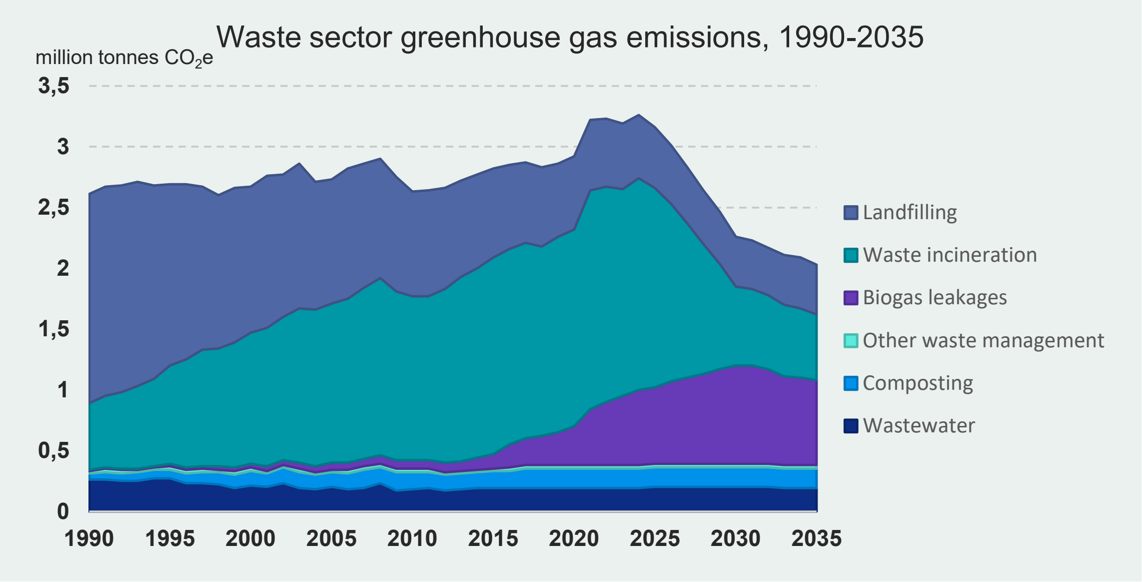
- Implementation of the *climate plan for a green waste sector and circular economy*, including measures to increase waste separation activities for recycling and reduction of incineration capacities
- Deployment of biogas production and methane leakage from biogas plants.
- Biological waste decomposition in landfills

[39] Note that, in CSO21, emissions of F gases were included under the waste sector. In CSO22, emissions of F gases have been distributed across activities and are therefore included as emissions in the sectors which have the activities that cause the emissions (see also memorandum on assumptions 9C).

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 25% of final heating consumption 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 (million tonnes CO_2e/year); 1990-2035



Total emissions by the sector for the period 1990-2030 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, methane leakage from biogas plants, composting and wastewater treatment. The energy-related emissions are mostly CO_2, whereas the waste-related emissions are primarily methane and nitrous oxide.

Waste incineration

Greenhouse gas emissions from waste incineration are expected to be 1.6 million tonnes CO_2e in 2025, 0.7 million tonnes CO_2e in 2030 and 0.5 million tonnes CO_2e in 2035. Relative to 2019, the predicted emissions constitute an increase of around 3% in 2025 and reductions of around 60% and 66% in 2030 and 2035, respectively.

The reduction in emissions from waste incineration is a consequence of initiatives under the climate plan for a green waste sector and circular economy, which includes a number of initiatives aimed at increased Danish waste separation and recycling and reduced incineration capacities. The combination of reduced volumes of waste suitable for incineration and reduced capacity is expected to lower the fossil share in waste suitable for incineration and limit the import of plastic-containing waste suitable for incineration, thus ultimately reducing the sector's greenhouse gas emissions.

Landfilling

It is assumed that emissions of methane from landfills will be reduced from 0.6 million tonnes CO_2e in 2019 to 0.5 million tonnes CO_2e in 2025 and around 0.4 million tonnes CO_2e in 2030 and 2035, corresponding to a reduction of 17% and 32%, respectively, compared to 2019. The reduction is due to the decomposition of landfilled biological waste and because, today biological waste is only being landfilled to a limited extent following the 1997 ban on landfilling waste suitable for incineration.

Methane leakage from biogas plants

Methane emissions in the form of leakage from biogas plants are expected to increase from 0.3 million tonnes CO_2e in 2019 to around 0.6 million tonnes CO_2e in 2025, around 0.8 million tonnes CO_2e in 2030 and 0.7 million tonnes CO_2e in 2035, corresponding to an increase of 133%, 200% and 159%, respectively, compared to 2019. The expected increase in greenhouse gas emissions is caused by an increase in biogas production, see chapter 7. The slight fall in emissions from 2030 to 2035 is due to the discontinuation of commitments for subsidy grants for certain types of biogas production.

The expected methane leakage from biogas plants is considerably higher in CSO22 compared to previous years' CSO reports. This is because updated knowledge about current methane leakage from biogas plants means that the assumed leakage rate for projected years has been increased from 1% to just under 3%.

Composting

Emissions of methane and nitrous oxide from composting are expected to amount to 0.2 million tonnes CO_2e in 2025, 2030 and 2035, respectively. Emissions from composting are therefore not expected to change significantly relative to 2019. The reason for this is that composted amounts are expected to remain relatively stable up to 2035.

Wastewater treatment

Emissions of methane and nitrous oxide from wastewater treatment are expected to amount to around 0.2 million tonnes CO_2e in 2025, 2030 and 2035, respectively. Emissions from wastewater treatment are therefore not expected to change significantly relative to 2019.

9.2 Uncertainty

There are uncertainties associated with the projection of waste sector emissions. In order to examine the significance of the most important uncertainties for the projection results, CSO22 includes the following sensitivity calculations:

- Capacity in the waste incineration sector
- Methane leakage from biogas plants

Capacity in the waste incineration sector

On the basis of the climate plan for a green waste sector and circular economy, CSO22 assumes that total annual environmentally approved capacity in the waste incineration sector will be reduced by 30% in 2030 compared to 2020. This capacity adjustment will be realised through implementation of a tendering model with an option to introduce supplementary measures if capacity developments do not follow developments in waste volumes.

A sensitivity calculation has been performed to illustrate possible developments in the sector's greenhouse gas emissions if the capacity adjustment follows the phase-out of defunct kiln lines at Danish installations. This sensitivity calculation therefore assumes that environmentally approved capacities will be adjusted as existing kiln lines age and therefore require major reinvestment. The calculation is based on information from dedicated and multi-fired incineration plants on their expectations about when they will need to reinvest in their 42 existing kiln lines. Assuming the above, it is expected that the target of a 30% reduction in incineration capacity stipulated in the climate plan for a green waste sector and circular economy will be met in 2035 and with this later phase-in the sector's CO_2 emissions become around 0.6 million tonnes higher in 2030 compared to the CSO22 basic scenario.

Methane leakage from biogas plants

As mentioned, expected methane leakage from biogas plants is higher in CSO22 compared to previous climate projections. Amongst other things, this is because new knowledge has been obtained about current methane losses of biogas plants. However, there is still considerable uncertainty associated with expected methane leakage, and a sensitivity calculation has therefore been prepared which assumes that new plants will have very low emissions and that old plants will be improved so that the average leakage rate is reduced to 1-1.5% in 2030. Assuming this, it is estimated that total emissions associated with methane leakage from biogas plants will be reduced by about 0.4-0.5 million tonnes CO_2e in 2030 compared to the CSO22 basic scenario.

10 Agriculture, agricultural land, forests, horticulture and fisheries

This chapter describes expected developments in emissions and removals by:

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

The agricultural processes, agricultural land, forests, horticulture and fisheries sector emitted 15.7 and 15.9 million tonnes CO_2e, respectively, in 2019 and 2020, corresponding to 33% and 35%, respectively, of total Danish emissions. In 2025, 2030 and 2035, the sector is expected to emit 16.7, 15.1 and 14.5 million tonnes CO_2e, respectively, corresponding to 40%, 45% and 48%, respectively, of total Danish emissions. The expected changes in sector emissions are due in particular to the following expectations:

- A drop in emissions from agricultural processes due to a drop in emissions from manure management and fertiliser use on fields following from the implementation of new policy measures in the area, for example.
- A drop in emissions from agricultural land due primarily to an expected increase in the land area of cultivated carbon-rich soil set aside and rewetted. Mineral soils

are expected to be sources of CO_2 removal from 2020 until 2035 as a result of a higher increase in crop yields and the application of straw and plant residues from catch crops, for example.

- Decreasing carbon sequestration in Danish forests as a consequence of expected tree harvesting,

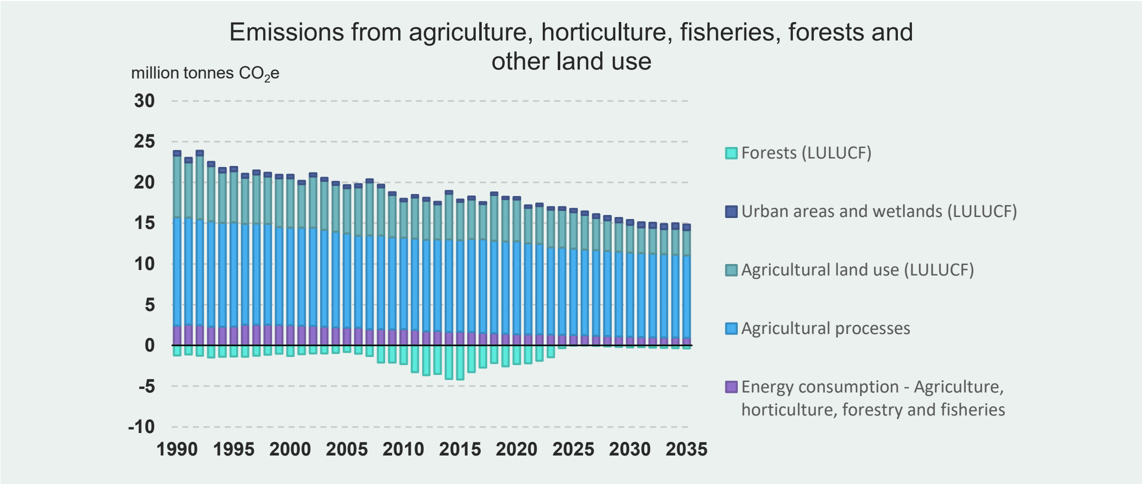
10.1 Total emissions from agriculture, agricultural land, forests, horticulture and fisheries.

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.

Danish forests have for many years acted as net removers of CO_2 through increases in forest carbon stocks, but it seems this will change over the next couple of years, when forests will move from being net removers to becoming net emitters for a period.

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).

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



Total CO_2e emissions from agricultural processes, agricultural land, forests, horticulture and fisheries in 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 68% of total emissions from the sector in 2030, while the LULUCF sectors and energy consumption by agriculture, horticulture, forestry and fisheries are expected to account for around 25% and 7%, respectively.

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 fertiliser use in fields. For a more detailed description of emissions from agricultural processes, see CSO22 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 (Land Use, Land-Use Change and forestry), which also include emissions from forest land and other land use (built-up areas and wetlands). In CSO22 and associated sector memoranda, the LULUCF sector is divided into two main land categories: agricultural land, which is described in sector memorandum 10C, and forest land, which is described in sector memorandum 10D. For a more detailed description of emissions from these categories see these sector memoranda.

Emissions and removals by forest land:
Similarly, emissions and removals by forest land are calculated as changes in the carbon pools in live biomass, dead biomass, mineral soils and carbon-rich soils. When forests grow, their standing live biomass sequesters CO_2 from the atmosphere, and, in the long run, afforestation on agricultural land can eventually lead to CO_2 removal and accumulation in the growing stock. 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 CSO22 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 process heat, for example. Emissions associated with the sector's consumption of electricity and district heating are included under the electricity and district heating sector in chapter 8. For a more detailed description of emissions from energy consumption in agriculture, horticulture, forestry and fisheries, see CSO22 sector memorandum 10A on energy consumption in agriculture, horticulture, forestry and fisheries.

10.2 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 come from three main sources, see text box 1 in sector memorandum 10B.

Emissions from agricultural processes were reduced from 13.3 million tonnes CO_2e in 1990 to 11.4 million tonnes CO_2e in 2020. This trend is expected to continue up to 2030, when emissions are expected to be 10.3 million tonnes CO_2e, corresponding to a reduction of around 23% compared to 1990. The drop in emissions from 2020 to 2030 stems from a drop in emissions from manure management and fertiliser use on fields of 0.9 and 0.5 million tonnes CO_2e, respectively, following new policy measures. Conversely, emissions from livestock digestion are expected to increase in the period from now and until 2030 as a result of an expected increase in livestock populations and increased milk yields.

CSO22 includes new policy measures adopted in the area, including, in particular, measures following from the agreement on a green transition of the agricultural sector and expected further proliferation of environmental technologies. The measures that have been included following the agreement on a green transition of the agricultural sector include reduction requirements for livestock digestion, more frequent slurry flushing, as well as other measures to reduce nitrogen leaching from the root zone.

Livestock digestion

Emissions mainly stem from cattle production, in which dairy cattle comprises the largest source. Total emissions from livestock digestion are expected to increase from 4.1 million tonnes CO_2e in 2020 to 4.4 million tonnes CO_2e in 2030. After 2030, emissions are expected to remain more or less stable in the absence of new policy measures. The increase is due to an expected increase in the population of dairy cattle, in particular, up to 2030 and increased milk yields as a result of genetic improvement, increased feed intake and optimised feed composition. Table 1 shows the expected increase in dairy cattle populations and the 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 assumptions 10B for details).

Table 10.1: Number of dairy cattle and other cattle, and emissions from their digestion in 2020, 2025 and 2030

Category of animal	2020	2025	2030
Dairy cattle	566,986	572,204	590,674
Other cattle	1120575	1129783	1140204
Enteric emissions from cattle (million tonnes CO_2)*	3.6	3.7	3.9

*Cattle account for around 87% of emissions from livestock digestion. The digestion of pigs, horses, deer, poultry and mink is also associated with emissions of small amounts of CH_4.

CSO22 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 following from an increase in dairy cattle stocks and increased productivity.

Manure management

Emissions from manure management were 3.1 million tonnes CO_2e in 2020 and are expected to fall to 2.2 million tonnes CO_2e in 2030. After 2030, emissions are expected to stabilise at the 2030-level 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 2020, 2025 and 2030

Category of animal	2020	2025	2030
Sows	1,054,896	1,016,707	930,713
Piglets	33,246,324	36,469,741	36,458,309
Slaughter pigs	19,066,047	21,806,322	21,650,801
Manure emissions from pigs (million tonnes CO_2e)*	1.5	1.1	0.9

*Pigs account for around 47% (2020) and 43% (2030) of emissions from manure management. Cattle account for 45% (2020) and 50% (2030).

Although no large change in pig production is expected in the period from 2020 and up to 2030 (table 2), the share of emissions from manure management linked to pig production is expected to fall from around 47% in 2020 to 43% in 2030. In particular, this is because CSO22 includes a requirement for more frequent slurry flushing in pig sheds from 2023, as adopted as part 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 stables and air purification; technologies that affect nitrous oxide 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.

Fertiliser use on fields

Nitrous oxide emissions from fertiliser use on 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 4.2 million tonnes CO_2e in 2020 to 3.8 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 2020 to 2030 is due to an increased utilisation requirement for livestock manure, increased expectations about extensification, and the permanent set-aside of agricultural land following the agreement on a green transition of the agricultural sector and the implementation of CAP 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 2020, 2025 and 2030

	2020	2025	2030
Nitrogen (N) from artificial fertilisers (kt N)	252	203	197
Emissions from artificial fertilisers (million tonnes CO_2e)	1.1	0.8	0.8

*Artificial fertilisers account for 25% (2020) and 22%. (2030) of emissions from fertiliser use on fields.

10.3 Emissions from agricultural land use

Emissions from agricultural land use include CO_2e removals and emissions by cultivated fields and grassland, and these are estimated as part of LULUCF emissions. Emissions are expected to fall from 5.1 million tonnes CO_2e in 2020 to 3.4 million tonnes CO_2e in 2030 and 3.1 million tonnes CO_2e in 2035. The drop is largely due to measures concerning permanent set-aside and rewetting of carbon-rich soils because emissions following from cultivating and draining carbon-rich soils account for the majority of total emissions from agricultural land use. There are also emissions and removals by mineral soils and emissions from carbon pools in live and dead biomass.

Just under 6% of the agricultural land area in Denmark is carbon-rich soils (see table 10.4), and the majority of emissions came from these soils in 2020 and the same will be true in 2030. Mineral soils, which make up by far the majority of the agricultural land area, are highly affected by the weather, and this can lead to both net removals and net emissions of CO_2. Predicting the carbon pool changes in mineral soils is therefore challenging.

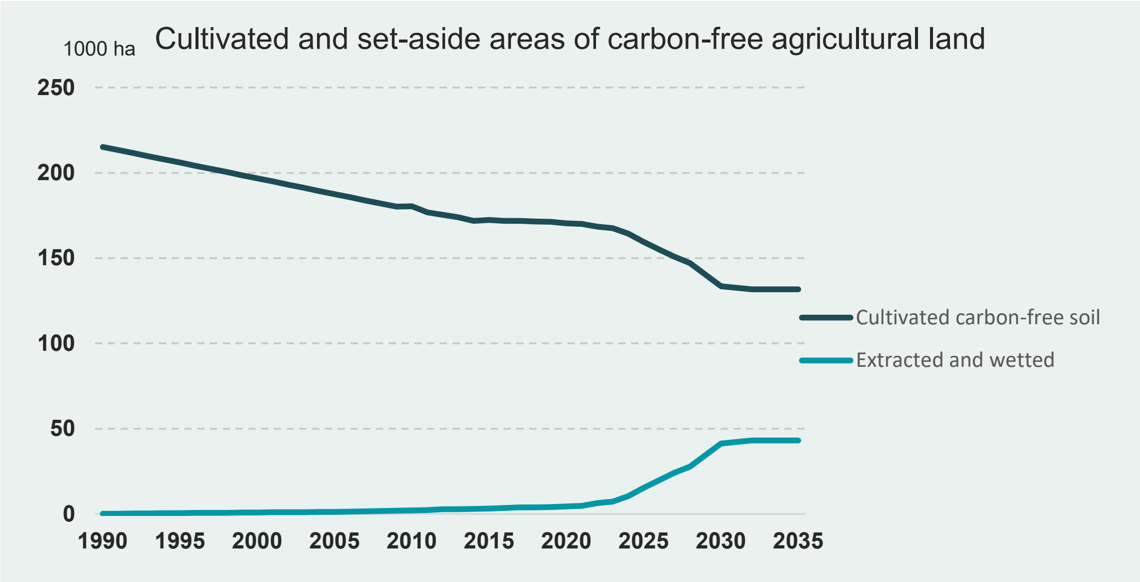
Table 10.4: Agricultural land, breakdown and emissions, including non-CO_2, for mineral soils and carbon-rich soils (excluding emissions from biomass)

	Agricultural land area (ha)				
	1990	2020	2025	2030	2035
Mineral soils	2,924,266	2,800,408	2,767,428	2,726,206	2,710,717
Carbon-rich soils	215,290	170,429	159,597	133,488	131,688
	Emissions (million tonnes CO_2e)				
Mineral soils	1.1	-0.1	-0.4	-0.7	-0.7
Carbon-rich soils	6.4	4.8	4.5	3.7	3.7

Cultivated carbon-rich soils

Carbon-rich soils are defined as soils with at least 6% organic carbon content, and most of these soils were originally wet peat bogs. When these soils are cultivated, the soil is drained and as oxygen is added, the organic material in the soil decomposes, which leads to the release of CO_2. Emissions have fallen from 6.4 million tonnes CO_2e in 1990 to 4.8 million tonnes CO_2e in 2020. Emissions have fallen because the area of cultivated carbon-rich soils has been reduced after the carbon in the carbon-rich soils has been released and the area therefore has been reclassified from carbon-rich soil to mineral soil, which has a lower carbon content. Recent years have seen the establishment of political agreements allocating funding for setting aside cultivated carbon-rich soils and converting them to wetlands. This will mean a significant reduction in emissions. CSO22 expects that almost one quarter of the carbon-rich soils under cultivation in 2020 will have been set aside by 2030 (see figure 10.2).

Figure 10.2: Carbon-rich agricultural land, cultivated and set-aside areas, from 1990 to 2035



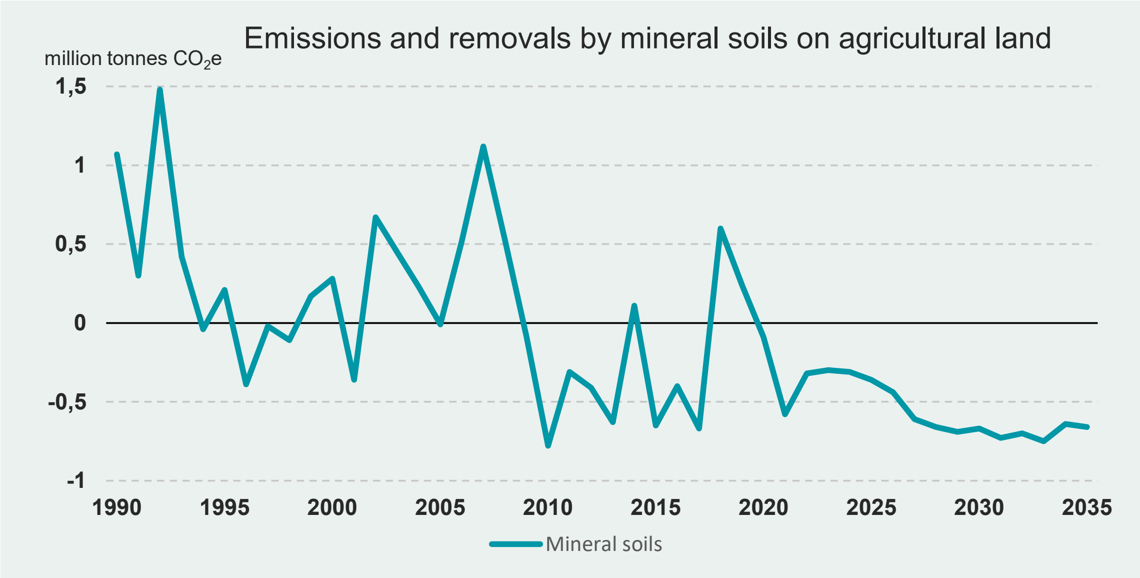
A further reduction is expected up to 2035 landing at around 3.7 million tonnes CO_2e. The further projected reduction is based on an expected permanent set-aside and rewetting of carbon-rich soils following from policies adopted and funding allocated from 2018 and onwards, including set-aside schemes under the 2020 Finance Act and the 2021 Finance Act, the agreement on a green transition of the agricultural sector and CAP 2023-27.

Mineral soils

Mineral soils today make up 94% of agricultural land in Denmark and are defined as soils with at least 6% organic carbon content. CO_2 emissions and removals by mineral soils depend on the relationship between the addition of organic material (plant material and livestock manure), weather conditions, soil type and cultivation history. Addition of organic material and weather conditions are factors that change considerably across the years. As a result there is large annual variation with regard to changes in the carbon pool in mineral soils, which can lead to either net emissions (in

2018, for example) or net removals (in 2010, for example). This is evident from historical emissions, see figure 10.3.

Figure 10.3: CO_2e emissions (positive) and removals (negative) by mineral soils in agricultural land from 1990 and projected up to 2035



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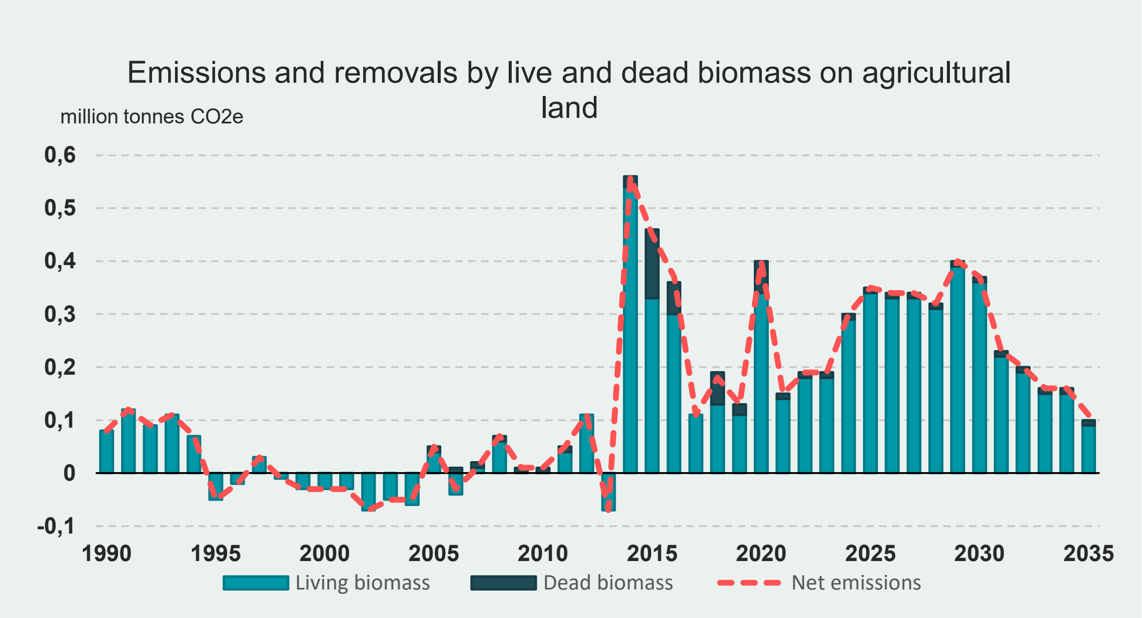
The projection of carbon pool changes in mineral soils also show annual variation in emissions/removals. The modelling takes account of the temperature difference between eight parts of Denmark (northern Jutland, southern Jutland, eastern Jutland, western Jutland, Funen, the capital region/north Zealand, Zealand incl. Lolland-Falster and Bornholm) by using temperature scenarios drawn up by the Danish Meteorological Institute. Note that 2021 has been modelled with observed temperatures, and therefore it differs from the other projected years for which a temperature increase has been assumed. The temperature rise will entail a lower uptake (around 0.3 - 0.4 million tonnes CO_2) in the period 2022-2026, after which the uptake will increase to around 0.6 - 0.7 million tonnes CO_2 from 2027 and for the rest of the period. This is due to the assumed increase in yields of, on average, 0.7% per year (varies between crops), and because, as a consequence of the agreement on a green transition of the agricultural sector, more catch-crops area has been assumed, as well as more area with grass compared with cereals.

Live and dead biomass

Changes in the carbon pool of biomass may lead to emissions and uptake of CO_2 and have been calculated for both live and dead biomass (see figure 10.4). Live biomass includes fruit trees, berry bushes, poplar, willow and other hardy perennial crops, as well as non-productive elements such as windbreaks and thickets in fields. According to IPCC’s calculation rules, changes in pools are calculated every year, and for this reason single-year crops do not give rise to neither emissions nor uptake at national level. The annual changes in the carbon pool which lead to emissions and uptake are thus due to growth, planting or removal of these plants. Emissions from the carbon pool of dead biomass are due to changes in land use when forest is converted to agricultural land. The left-over dead biomass from the forests (dead leaves, twigs and partly decomposed tree trunks) is degraded later, and this leads to emissions. These emissions are reported under agricultural areas if the deforestation is for cultivated fields or grassland. In the projection years, biomass is expected to emit between 0.1 and 0.4 million tonnes CO2e annually.

Figure 10.4: Emissions and removals by live and dead biomass on agricultural land (without non-CO_2 from burning)



10.4 Emissions and removals by forests

Trees uptake CO_2 while they grow and store carbon in hardy biomass. Besides this, carbon can be stored in harvested wood products[40]. Net changes in these two carbon pools can either entail net emissions or net removals of CO_2. Whether forests and wood products contribute net emissions or net removals depends on the relationship between annual growth and annual felling/decomposition. Apart from changes in carbon pools, the calculation includes emissions of CO_2, methane and nitrous oxide from forest land.

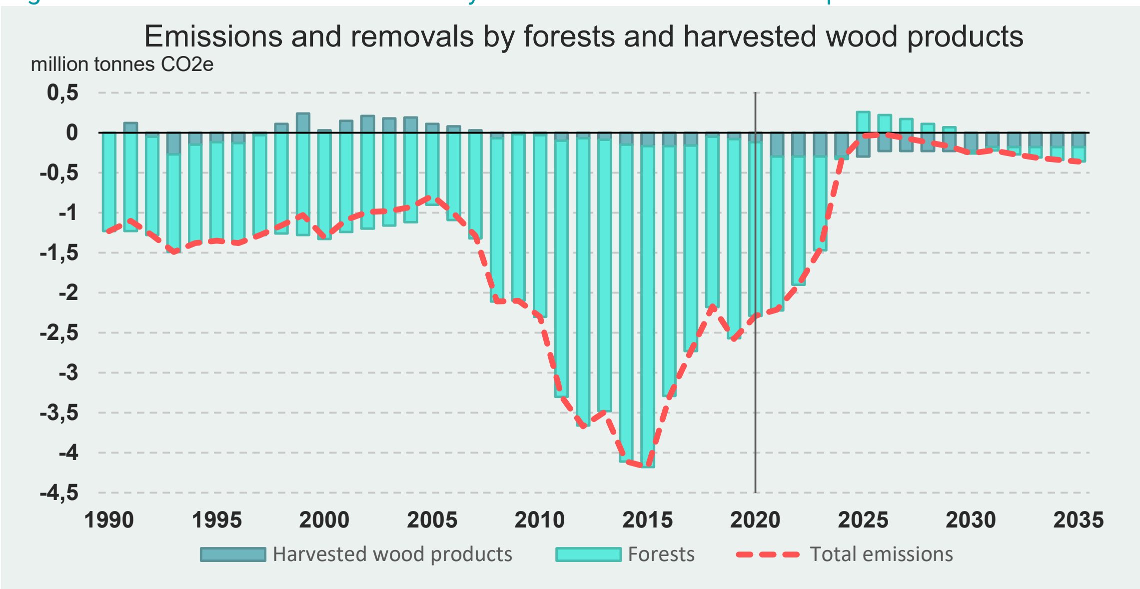
From 1990 to 2020, Danish forest land and wood products had annual net removals of 1.9 million tonnes CO_2e. Up to 2035, annual net removals are expected to fall to 0.5 million tonnes CO_2e on average. Forests and harvested wood products are expected result in net removals of 0.26 million tonnes CO_2e in 2030 to 0.36 million tonnes CO_2e in 2035. Figure 10.5 shows changes in emissions and removals by forests and harvested wood products from 1990 to 2035.

The drop in net removals is primarily due to expected smaller net removals of CO_2 by forests up to 2035 In 2025 to 2029, slight net emissions by forests are expected. The

[40]Harvested wood products are the part forest harvesting that is marketed as industrial wood or merchantable wood. This is sawn wood and wood boards used for building materials.

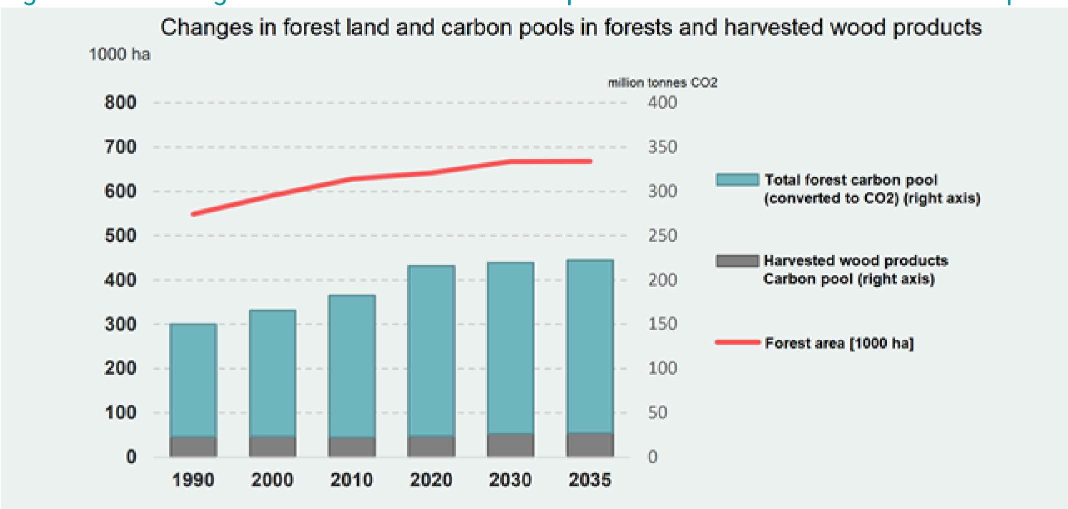
reason for this includes regeneration of Danish forests, as old trees are expected to be felled and replaced by new trees.

Figure 10.5: Emissions and removals by forests and harvested wood products



Emissions and removals by forests and wood products are a result of developments in the total forest land area, changes in the carbon pool in forests, and changes in the carbon pool in wood products. The area of forest land in Denmark has been increasing since 1805, and is expected to increase further up to 2035 following afforestation. The forest carbon pool has been increasing since 1990. From 2020, this carbon pool is expected to stabilise, however, in part because of felling. The carbon pool in wood products is expected to increase from 1990 up to 2035 (see figure 10.6), because overall more input is being produced for the pool than drainage in the form of timber products being disposed of.

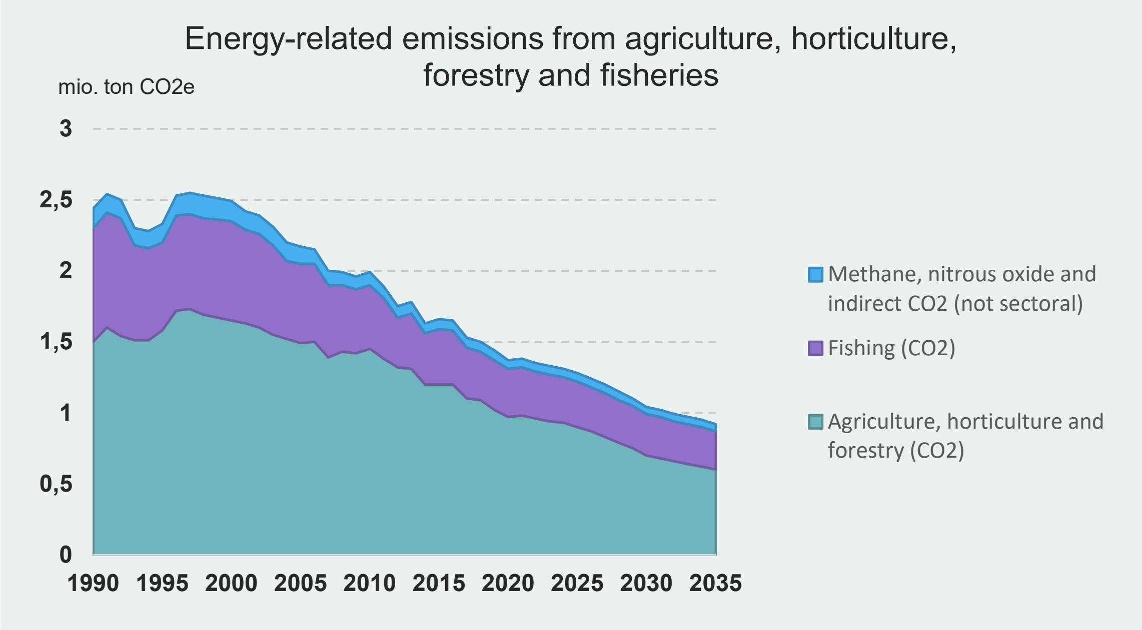
Figure 10.6: Changes in forest land and carbon pools in forests and harvested wood products



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

Emissions from energy consumption in agriculture, horticulture, forestry and fisheries are expected to be reduced from 1.4 million tonnes CO_2e in 2020 to around 1 million tonnes CO_2e in 2030 (see figure 10.7). Up to 2035, a further reduction to 0.9 million tonnes CO_2e is expected in the absence of policy measures. In 1990, emissions were 2.4 million tonnes CO_2e and the expected reduction between 1990 and 2030 thus corresponds to a reduction of around 57%.

Figure 10.7: Emissions from energy consumption in agriculture, horticulture, forestry and fisheries



For agriculture, horticulture and forestry, sector emissions from energy consumption come mainly from consumption of fossil fuels in internal transport (including especially operation of agricultural machinery) and process heat (e.g. for heating hothouses and livestock buildings). In 2020, energy-related CO_2 emissions from agriculture, horticulture and forestry were at around 1 million tonnes. Emissions are expected to fall by about 0.3 million tonnes CO_2 up to 2030. Up to 2035, a further reduction to 0.1 million tonnes CO_2 is expected in the absence of new policy measures. The reduction is driven by continuous energy-efficiency improvements and conversion away from fossil fuels for heat pumps linked to the sector's need for process heat.

CO_2 emissions by the fisheries sector are mainly linked to diesel fuel consumption by fishing vessels and amounted to 0.34 million tonnes CO_2 in 2020. From 2020 and up to 2035, energy-related emissions from fisheries are assumed to decrease further to 0.29 million tonnes CO_2 in 2030 and 0.27 million tonnes CO_2 in 2035. The drop in emissions is driven by falling activity as well as structural changes in the form of a continued change of the fishing fleet towards fewer but larger and more energy-efficient vessels.

10.6 Uncertainty

Emissions from agricultural processes

Calculation and projection of emissions from agricultural processes are associated with uncertainty with regard to the methods of calculation and activity data. The uncertainty is assessed to be significantly higher in the projection than in the historical emissions, as a number of significant variables are difficult to predict. These include changes in the number of livestock and hectares of crops, which depend on market conditions in the EU and consumer preferences. Assumptions of either 15% more or 15% fewer pigs (sows, piglets, porkers) in 2030 will increase or reduce agricultural emissions by almost 0.2 million tonnes CO_2e, corresponding to around 2% of total emissions from agricultural processes in 2030 (see table 10.5). Similarly, it has been assessed that a development with either 10% more or 10% fewer piglets will either cut or increase agriculture's emissions by 0.1 million tonnes CO_2e in 2030, corresponding to around 1% of emissions by agriculture in 2030.

Table 10.5: Results of sensitivity analyses, million tonnes CO_2e

	CSO22	+ 15% pigs	- 15% pigs	+ 10% exported piglets	- 10% exported piglets
Emissions 2030	10.3	10.6	10.1	10.3	10.4
Total change compared with CSO22		0.2	-0.2	-0.1	0.1

Source: DCE

The agreement on a green transition of the agricultural sector and Denmark's National CAP Strategic Plan have been included in CSO22. As actual implementation of these agreements has not yet been finalised, assumptions in future climate projections may have to adjusted.

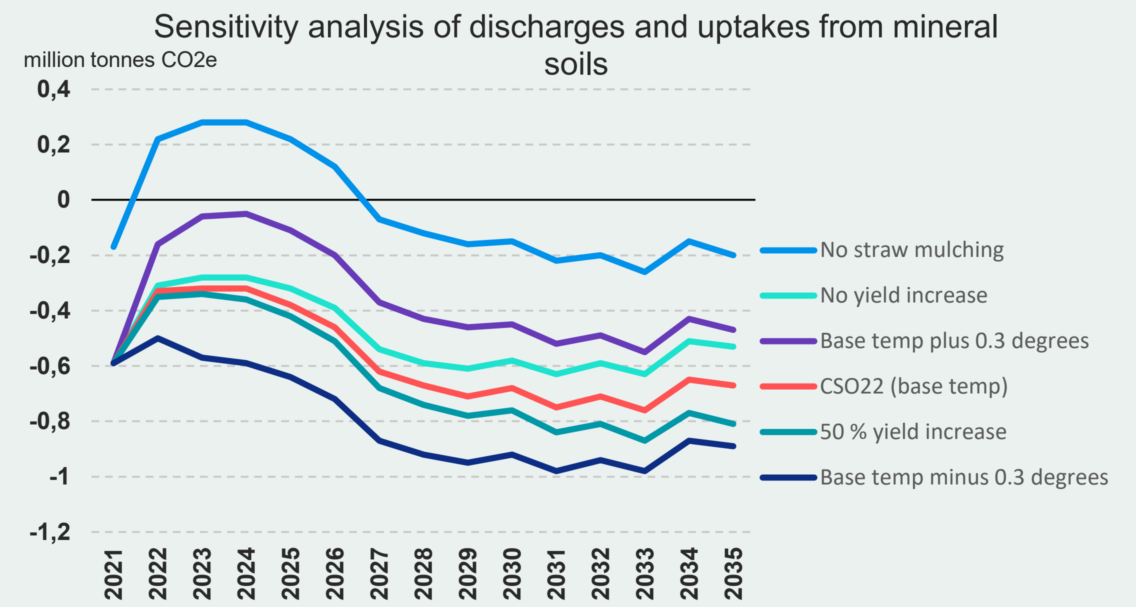
Emissions from agricultural land use

Projections of emissions and removals stemming from agricultural land use are characterised by considerable uncertainty, and this also applies for the historical greenhouse gas emissions inventory. Changes in organic carbon pools are difficult to quantify because of methodological challenges. Changes in the pools are a result of complex interactions in the soil-plant-atmosphere in the carbon cycle

Uncertainty is linked to both the size of emissions and the area of the carbon-rich agricultural soils that, quantitatively, are the largest source of emissions from agricultural land use. Similarly, the extent and speed of set-aside of carbon-rich agricultural land are also uncertain. The Danish Centre for Environment and Energy (DCE) has assessed that emissions will be around 0.5 million tonnes CO_2 higher in 2030 than the estimate in CSO22 if only 50% of specified area is set aside as wetlands. The Ministry of Climate, Energy and Utilities has initiated research work to ensure better knowledge about how emissions from carbon-rich soils can be calculated more accurately.

The model (C-TOOL), which projects emissions and removals by mineral soils, is particularly sensitive to assumed changes in temperature, rises in yields, straw mulching, use of catch crops and additions of other plant residues. Without inclusion of the rise in yields, mineral soils would in future emit more than 0.10 million tonnes CO_2 more annually, while an additional increase in yields of 50% more than assumed in CSO22 would increase removals by around 0.08 million tonnes CO_2 in 2030. A sensitivity analysis of the significance of straw mulching in C-TOOL shows that, if all straw were removed from fields, emissions would increase by around 0.5 million tonnes CO_2 in 2030 (see figure 10.8).

Figure 10.8: Sensitivity to assumed rises in yields, straw mulching and temperature increases in the calculation of emissions and removals by mineral soils



Source: DCE

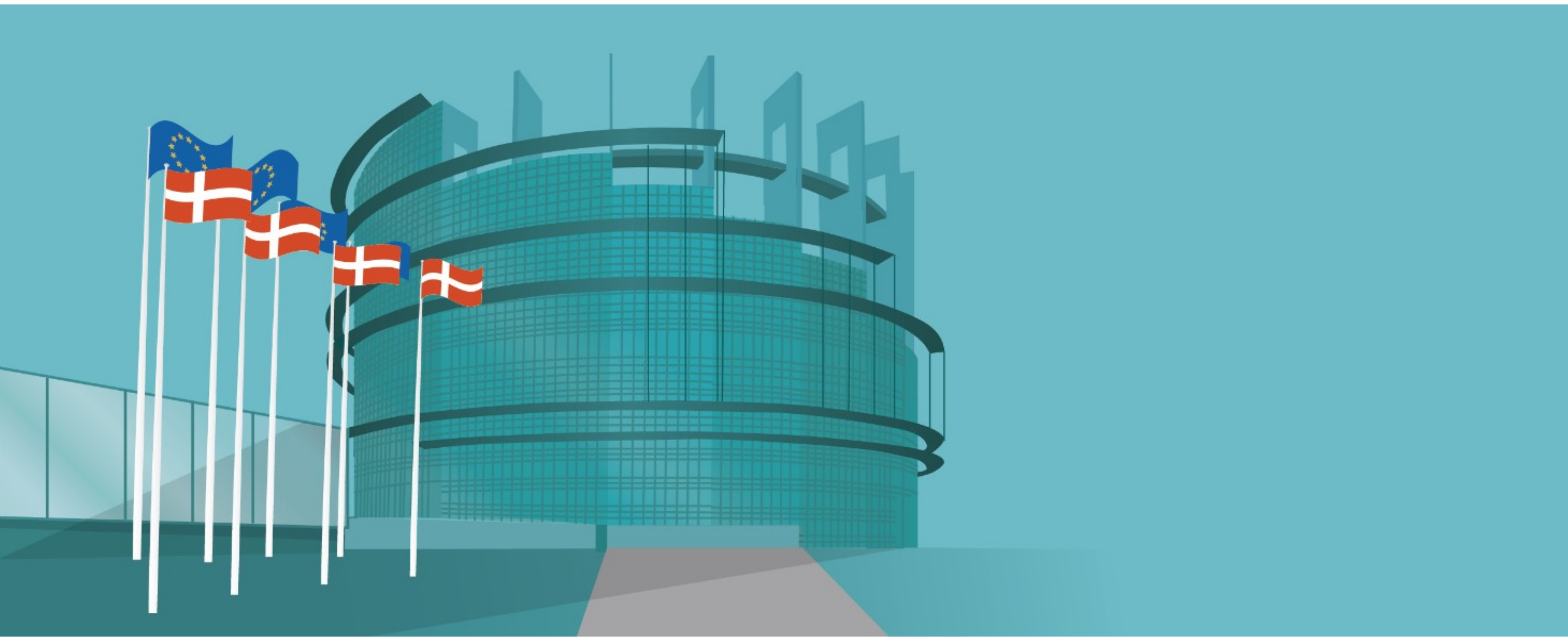
Analyses with different temperature scenarios show how sensitive the modelled changes in carbon pools in CSO22 are to changes in expected temperatures. An uncertainty analysis by the Danish Centre for Environment and Energy (DCE) with the C-TOOL model (see figure 10.8) shows that adding 0.3°C to the temperature scenario would reduce carbon uptake in the soil pool in 2030 by 0.23 million tonnes of CO_2. If the temperature were 0.3°C less than has been assessed by the Danish Meteorological Institute in the basic temperature scenario, it would cause further carbon uptake of about 0.24 million tonnes of CO_2.

Emissions and removals by forests

Calculation of historical emissions and removals by forests and wood products entails significant methodological and measurement uncertainty. This is because net emissions and removals are a result of small, relative changes in very large carbon pools.

In the projection, it is difficult to predict the extent of afforestation and felling and consequent regeneration of forests, because of the many players involved in the management of forest areas. Actual management of the forest area in the future depends on many factors, in particular the type and age of trees, but also finances, prices and demand as well as policy measures. For example, if only quick-growing conifers are planted, the annual net removals from afforestation will increase by 0.3 million tonnes CO_2e in 2035. Developments in the forest carbon pool up to 2035 are therefore associated with great uncertainty.

Emissions from energy consumption in agriculture, horticulture, forestry and fisheries
Projected energy consumption by agriculture, horticulture, forestry and fisheries is based on the expected development in economic activity. As these sectors are particularly sensitive to changes in market conditions, developments in economic activity are associated with significant uncertainty. Furthermore, it is currently uncertain whether, or to what extent over the projection period, the Danish fishing fleet or agricultural internal transport will be electrified and thus contribute to reducing energy-related emissions. Therefore, CSO22 has not included potential electrification of the Danish fishing fleet or agricultural internal transport.



11 Denmark's EU obligations

Denmark has a series of obligations in the EU under the 2030 climate & energy framework. At overall level, these are set out in the Governance Regulation (Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action). Denmark is therefore obligated, within the period 2021 to 2030, to:

a) reduce emissions in non-ETS sectors. The non-ETS sectors primarily comprise transport, agriculture, non-energy-intensive industries, waste/wastewater, small district heating and CHP plants, and households;
b) provide positive LULUCF climate accounts of emissions and removals by forests, cropland, grassland and wetlands according to specified criteria;
c) meet a number of obligations for the use of renewable energy and energy-efficiency improvements.

This chapter contains a status of progress with regard to when these obligations will be met under CSO22.[41] The conclusion is that Denmark will be able to live up to the relevant EU target for climate and energy.

The European Commission has presented the "Fit for 55" package, which involves tightening a number of targets in EU climate and energy legislation. As the proposals from the Commission are still under negotiation with the EU, and therefore these have

[41] See sector memoranda 11A and 11B for a more detailed description.

not been adopted, CSO22 has not taken into account a specific assessment of the status for these potentially significantly tighter targets. CSO22 shows the status for current targets and commitments: CSO22 is a frozen-policy projection.

11.1 Status of progress regarding climate commitments: Non-ETS emissions and LULUCF

Table 11.1 describes Denmark's EU commitments regarding non-ETS emissions and LULUCF emissions and takes stock of how these commitments are expected to be met under CSO22.

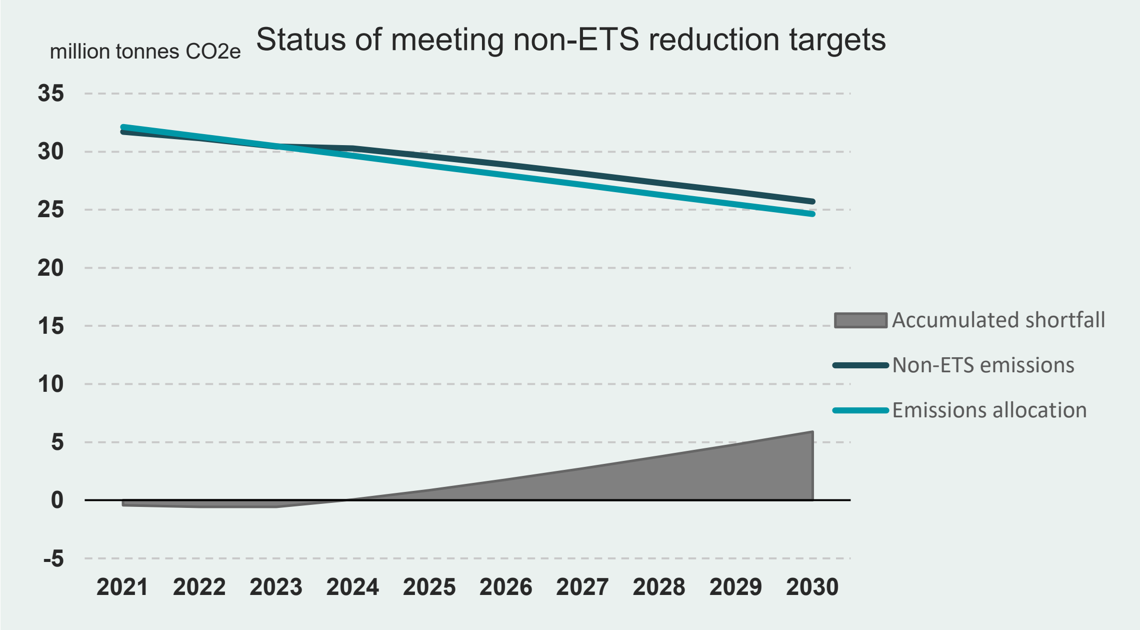
Table 11.1: Denmark's progress towards meeting its EU commitments with regard to non-ETS and LULUCF emissions

Indicator	Obligation	Expected status	Primary uncertainty
Reduction of non-ETS emissions	39% reduction in 2030 compared to 2005. The reduction has to follow a given reduction trajectory.	A cumulative gap of 5.9 million tonnes CO_2e is expected in the period 2021-2030. The commitment can be met without new initiatives, if it is decided to make use of LULUCF credits and/or ETS allowances.	Uncertainty relates in particular to the projection of livestock populations in agriculture and emissions from transport, as well as the share of biogas in mains gas. There is a high degree of uncertainty connected with estimating emissions from landfills and biogas plants.
LULUCF credits	The LULUCF sector must deliver positive climate accounts calculated according to specific calculation rules (the no-debit rules)	Met. Cumulative LULUCF credits will correspond to around 29 million tonnes CO_2e in 2030.	There is large uncertainty about estimates of future emissions and removals by forest land older than 30 years, as well as about emission factors for organic agricultural soils and removals by mineral soils in agriculture.

Figure 11.1 illustrates the development in non-ETS emissions and status of progress with regard to reduction obligations. As can be seen, in the period 2021 to 2023, non-ETS emissions are expected to be lower than the emission allocations by virtue of the current reduction trajectory. On the other hand, from 2024 to 2030, non-ETS emissions are expected to be higher.

Surplus emission allocations in individual years can be transferred to later years, and, overall, this means there will be an expected cumulative emissions gap of 5.9 million tonnes CO_2e in 2030. This shortfall can be offset by implementing further climate measures or by using part of the accumulated LULUCF credits and/or EU ETS allowances.

Figure 11.1: Status of progress towards non-ETS reduction targets, 2021-30



11.2 Status of progress for renewable energy and energy efficiency

Table 11.2 describes Denmark's EU obligations with regard to renewable energy and energy efficiency and gives a status report on the prospect of these obligations being met under CSO22.

Table 11.2: Status of progress towards Denmark's obligations in the EU with regard to renewable energy and energy efficiency

Indicator	Obligation	Expected status	Primary uncertainty
Renewables share (RES)	Ambitious contribution to the common EU renewable energy target of 32% for the EU as a whole.	Met. The renewables share is expected to be 64% in 2030. This clearly exceeds the 55% that was assessed as "sufficiently ambitious" by the European Commission in connection with NECP reporting (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	Met. RES-T is expected to reach 41% in 2030.	Degree of electrification and RES-E
Advanced biofuels in transport	At least At least 0.2% in 2022, 1.0% in 2025 and 3.5% in 2030 (calculated under the RES-T definition)	Obligations for 2022 and 2025 are expected to be met. It is currently not possible to predict with certainty whether the 2030 requirement will be met without additional measures. However, regulation of ILUC impacts or similar must be introduced from 2025. This is expected to have a positive effect on specific future compliance with the requirement for advanced biofuels, because it is expected to reduce consumption of first-generation biofuels, for example.	
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. RES-H&C is expected to exceed 60% from 2021, 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

Indicator	Obligation	Expected status	Primary uncertainty
Energy savings	0.8% annually from 2021 to 2030 relative to average energy consumption in the period 2016 to 2018.	Assessed to be met according to an analysis concluding that Denmark is on track to over-achieving the EU requirement for energy by 27% (see: "Danmark sparer på energien og står til at opfylde EU's krav om energibesparelser med 127 pct.")[42]	See the analysis that is the basis for this expectation

Figure 11.2 illustrates the trend in renewables shares.

The total share of renewables (RES) is expected to increase from 42% in 2020 to 64% in 2030. This does not include any statistical transfers between Denmark and other EU Member States. After statistical transfers, the total Danish renewables share was 32% in 2020.

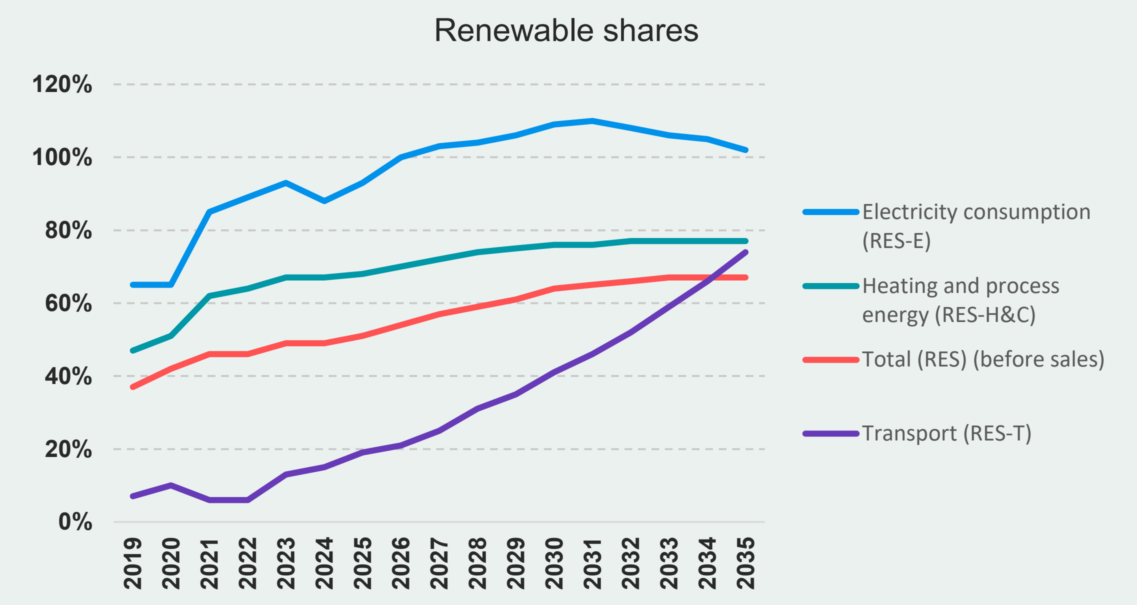
The renewables share in electricity consumption (RES-E) is expected to increase from 65% in 2020 to 109% in 2030 and to peak at 110% in 2031. After this, increasing electricity consumption is expected to exceed the deployment of renewable energy in electricity supply such that the renewables share will drop to 102% up to 2035. Contributions from the energy islands are not included in the above, but are dealt with in a partial alternative calculation, see the section below about uncertainty. Similarly, neither does the above include any increase in electricity consumption, e.g. for PtX plant.

The renewables share in heating and process energy (RES-H&C) is expected to increase from 51% in 2020 to 76% in 2030, which will be due in particular to an increasing renewables share in mains gas 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 9.6% in 2020 to 41% in 2030, which is due in particular to tighter requirements for biofuel blending in diesel and petrol, as well as to electrification of cars and vans and rail transport.

[42] https://kefm.dk/Media/C/4/Minianalyse%20-%20Energieffektivisering.pdf.

Figure 11.2: Renewables shares in total energy consumption, electricity consumption, heating and process energy, and transport



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 32% in 2020.

11.3 Uncertainty

Non-ETS emissions are particularly sensitive to developments in transport and agriculture, deployment of heat pumps in space heating and industry, as well as production, management and use of biogas.

Renewables shares in individual years are particularly sensitive to commissioning dates for offshore wind and solar PV. A partial alternative calculation shows that commissioning the energy islands will increase the renewables share in electricity consumption (RES-E) to 123% in 2030 and further to 138% in 2035 (with unchanged electricity consumption).

Finally, as noted above, in December 2020, the EU heads of state and government agreed to raise the 2030 emission reduction target from 40% (excluding LULUCF) to at least 55% (including LULUCF) compared to 1990. The European Commission has subsequently presented its "Fit for 55" package, which involves proposals for tightening the EU's climate and energy legislation. Amongst other things, the proposals entail a tightening of Denmark's climate and energy commitments in the EU. As the proposals from the European Commission are still under negotiation within the EU, and have therefore to be adopted, CSO22 does not assess the status of progress with regard to meeting these potentially significantly tighter targets. However, note that the European Commission proposes to tighten the above targets for non-ETS and LULUCF significantly, and the targets proposed for Denmark cannot necessarily be expected to be met with policies and instruments already adopted.

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)	Global Reports (GR)	Climate Programme (CProg) - Scenarios	Analysis assumptions for Energinet (AA)
Back-ground	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 Act	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.
Focus	Calculation of total Danish greenhouse gas emissions in accordance with the UN IPCC methodology (see also CSO22 memorandum on assumptions 2B on principles for calculation of emissions). In accordance with UN IPCC methodology, emissions from international shipping and air transport are not included in the projection.	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	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-	Projection of consumption and production of electricity and gas in Denmark.

	The UN IPCC methodology generally entails calculating emissions from the production side (rather than the consumption side).	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.	attainment than those prepared for the Climate Programme.	
Time hori-zon	Historical (from 1990 to 2020 in CSO22) and projected (from 2021 up to 2035 in CSO22).	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 (2020). There are no projections in GR22 (apart from the effect of the electricity trade balance on foreign emissions).	Scenarios have been prepared for 2030 and 2050. The scenarios for 2030 should be considered as steppingstones towards the scenarios for 2050.	At least up to 2045 for AA22.
Type of project -tion	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 CSO22 is 1 January 2022 (see also CSO22 memorandum on assumptions 2C on principles for frozen policy).			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, even if no specific measures are adopted to attain these. AA is therefore not based on a frozen-policy scenario.
Appli-cation	To examine to what extent Denmark's climate and energy targets and commitments will be met within the framework of current regulation. As a technical reference when planning new	Calculate 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%	AA are used by the Energinet to plan developments in the Danish electricity and gas transmission network.

	measures in the climate and energy area, and when assessing the impact of such measures.		target in 2030 and the zero-emissions target for 2050.	
Further information	https://ens.dk/service/fremskrivninger-analyser-modeller/klimastatus-og-fremskrivning-2022	https://ens.dk/service/fremskrivninger-analyser-modeller/global-afrapportering-2022	https://ens.dk/service/fremskrivninger-analyser-modeller/tekniske-analyser-til-baggrund-klimaprogram-2021 https://kefm.dk/aktuelt/nyheder/2021/sep/regeringen-fremskynder-klimaindsatsen-med-koereplan-til-ny-2025-deadline	https://ens.dk/service/fremskrivninger-analyser-modeller/analyseforudsaetninger-til-energinet

Appendix 2: List of CSO22 sector memoranda and memoranda on assumptions

In addition to the main report, CSO22 comprises 17 sector memoranda and 38 memoranda on assumptions. All of these memoranda are shown in the tables below.

Table A1.1: CSO22 sector memoranda

Memorandum no.	Sector memorandum
3A	Households
4A	Transport
4B	Consumption and composition of transport fuels
5A	Service sector
6A	Manufacturing industries and building and construction
7A	Production of oil, gas and renewable fuels
7B	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: CSO22 memoranda on assumptions

Memorandum no.	Memorandum on assumptions
0	Introduction to CSO22 assumptions material
1A	RAMSES model
1B	IntERACT model
1C	FREM transport model
1C-Vej	Road transport in FREM
1C-BBM	ART car population model
1C-BVM	Car type choice model
1D	Calculation methods from the Danish Centre for Environment and Energy (DCE) for agriculture, LULUCF and waste
2A	New policies included in CSO22, as well as policies that are not included
2B	Emission inventory principles

Memorandum no.	Memorandum on assumptions
2C	Frozen-policy principles
3A	Fuel prices
3B	CO_2 allowance price
3C	Electricity production capacities abroad and interconnectors
3D	Assumptions about economic growth
4A	Car type choice assumptions
4B	Renewable fuels
4C	Cross-border trade in fuels
5A	Individual heating by households
5B	Household use of appliances
6A	Data centres
6B	Cement production
7A	Oil-gas production
7B	Refineries
7C	Biogas production
7D	PtX
7E	CCS
8A	Offshore wind
8B	Onshore wind
8C	Solar PV
8D	Thermal production capacity (excl. waste incineration)
9A	Waste incineration
9B	Waste (excluding waste incineration) and wastewater
9C	F gases
10A	Energy consumption in agriculture, horticulture, forestry and fisheries
10B	Agricultural processes
10C	Agricultural land and other land (excluding forests)
10D	Forest land and harvested wood products

Appendix 3: List of CSO22 datasheets

A number of data sheets are published in the context of CSO22. The data sheets are listed in the table below. (The data sheets are only available in Danish and the column 'File name' therefore lists the Danish file names).

Table A2.1: CSO22 datasheets

File name	Description
CSO22 results - numbers behind the figures	• Includes the data behind figures in the CSO22 main report and sector memoranda
CSO22 assumptions - numbers behind the figures	• Includes the data behind figures in CSO22 memoranda on assumptions
CSO22 Common Reporting Format table	• Emission inventories per greenhouse gas type for the years 1990-2035 Statistical years are observed years, while the projection period uses 'normal years'. Statistical years are observed years, while the projection period uses 'normal years'. • CSO22 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. • CSO22 has been calculated using the new global warming potential factors from the IPCC's 5th Assessment Report (AR5).
CSO22 Common Reporting Format table (using AR4 GWP factors)	• CSO22 calculated using the global warming potential factors from the IPCC's 4th Assessment Report (AR4). Published to show the significance of the change in GWP factors from AR4 to AR5 (see also memorandum on assumptions 2B).
Energy Balance	• National energy balance for fuels for the years 2015-2035
Sector data sheets	• Electricity and district heating • Electricity system time series • Transport • Agriculture • LULUCF

Appendix 4: The relationship between CSO22 sectors and CSO21 sectors and CRF table

The relationship between CSO22 sectors and CSO21 sectors

As in CSO21, in CSO22 emissions are broken down by eight sectors and CCS. The only change in the sectoral division between CSO21 and CSO22 is that F gases have been broken down into the service sector, manufacturing industries, households and transport (see CSO22 memorandum on assumptions 9C about F gases).

Table A3.1: CSO22 sectors

CSO22 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	
Electricity and district heating	Excluding emissions from waste incineration
Waste and wastewater	Including emissions from waste incineration, landfills, wastewater, composting and leakage 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 sectors in CSO22, the technology is instead dealt with as a separate source of negative emissions.

The relationship between CSO22 sectors and the CRF tables

The sectoral division in CSO22 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 CSO22 sectors (here identified by chapter numbers in the main report). F gases are broken down by sectors on the basis of the distribution key in CSO22 memorandum on assumptions 9C.

Table A4.1: The relationship between CRF categories and CSO22 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

CRF code	Description	CO_2, CH_4, N_2O, Indirect CO_2
3H	Urea application	10
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	09
5C	Incineration and open burning of waste	09
5D	Wastewater treatment and discharge	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: Comparison of total net emissions in CSO22 and CSO21

This appendix compares total emissions in CSO22 with total emissions in CSO21. In this connection, note that it generally will not be possible to clearly explain all changes from CSO21 to CSO22, as these changes will be the total result of both policy measures and changed general assumptions regarding, for example, prices and technology, as well as derived effects between sectors. In some cases, the results may also be affected by methodology and model development (e.g. as described in the memoranda on assumptions in CSO22).

Figure App.5.1: Total net emissions in CSO22 and CSO21

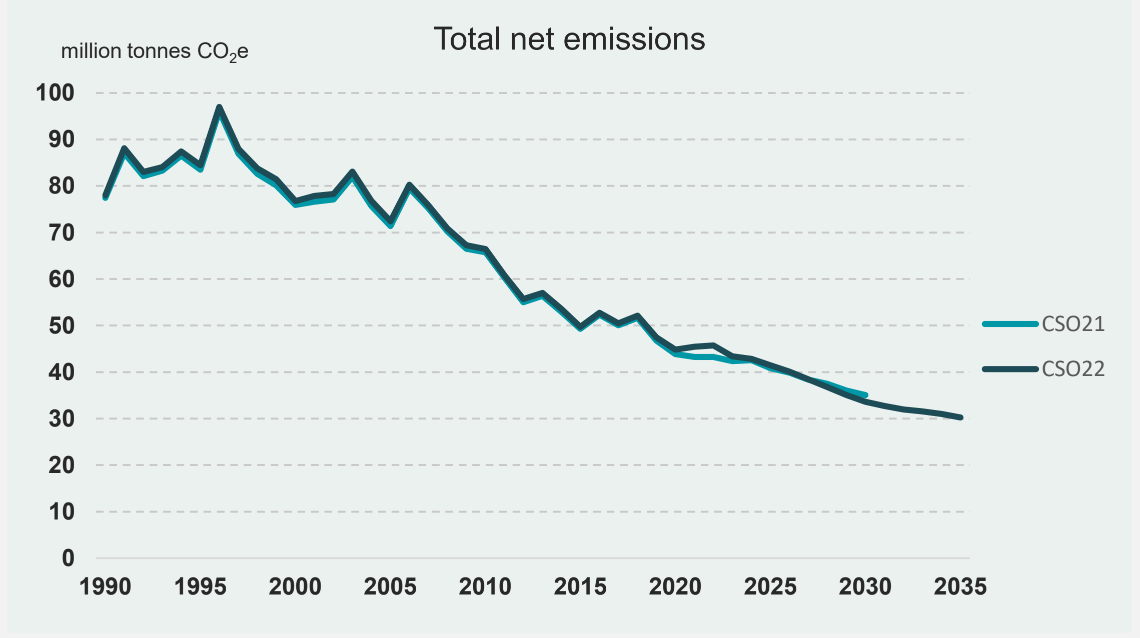


Figure App. 5.1 shows total net emissions in CSO22 and CSO21, respectively The difference in the historical years is primarily due to changes in estimates regarding LULUCF and, to a lesser extent, estimates regarding agricultural processes.[43] The difference in the projection period also covers a number of changes in different directions in the different sectors (see also section 3.1 in the sector memoranda,

[43] With regard to LULUCF, this is primarily changes in the calculation of emissions from forests and harvested wood products (see sector memorandum 10D), as well as cultivated areas (see sector memorandum 10C), whereas for agricultural processes it relates to emissions from fertiliser use (due to methodological changes in the calculation of emissions from crop residues, see sector memorandum 10B).

which compare emissions from the individual sectors in CSO22 and CSO21, respectively).

As mentioned in section 2.1 in chapter 2, developments in emissions from CSO21 to CSO22 are the result of a combination of new policy measures, revised expectations about price and market developments, and an updated data basis. The effects of these factors on sector emissions are described in the sector chapters of the report and in more detail in the underlying sector memoranda. Note in particular that the difference between CSO22 and CSO21 in 2021 and 2022 is, among other things, due to higher emissions from the electricity and district heating sector in these years in CSO22 because higher fossil fuel prices increase electricity prices, both in Denmark and internationally, and this makes it beneficial in the short term to increase Danish electricity production from coal and biomass (see sector memorandum 8A).

Appendix 6: Total biogenic energy-related CO_2 emissions in CSO22

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 CSO22 memorandum on assumptions 2B). 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 2020, when they totalled 18.6 million tonnes CO_2. During the first years of the projection period, total biogenic energy-related CO_2 emissions will increase further to 26.5 million tonnes CO_2 in 2023, after which they will fall again, to 21 million tonnes CO_2 in 2030 and 18.2 million tonnes CO_2 in 2035. The high level of energy-related biogenic CO_2 emissions from 2021-23 should be considered in light of the high fossil fuel prices in the projection for these years (see CSO22 memorandum on assumptions 3A). The increase in biogenic energy-related CO_2 emissions stems in particular from the electricity and district heating sector, in which the significant short-term increase in fossil fuel prices will lead to a higher percentage of electricity and district heating production based on biomass (and on coal, see sector memorandum 8A). The electricity and district heating sector is generally the sector that accounts for the largest share of total biogenic energy-related CO_2 emissions in the projection period. Thus, in 2030, the electricity and district heating sector will account for 49% of these emissions.

Figure App.6.1: Total biogenic energy-related CO_2 emissions by sectors

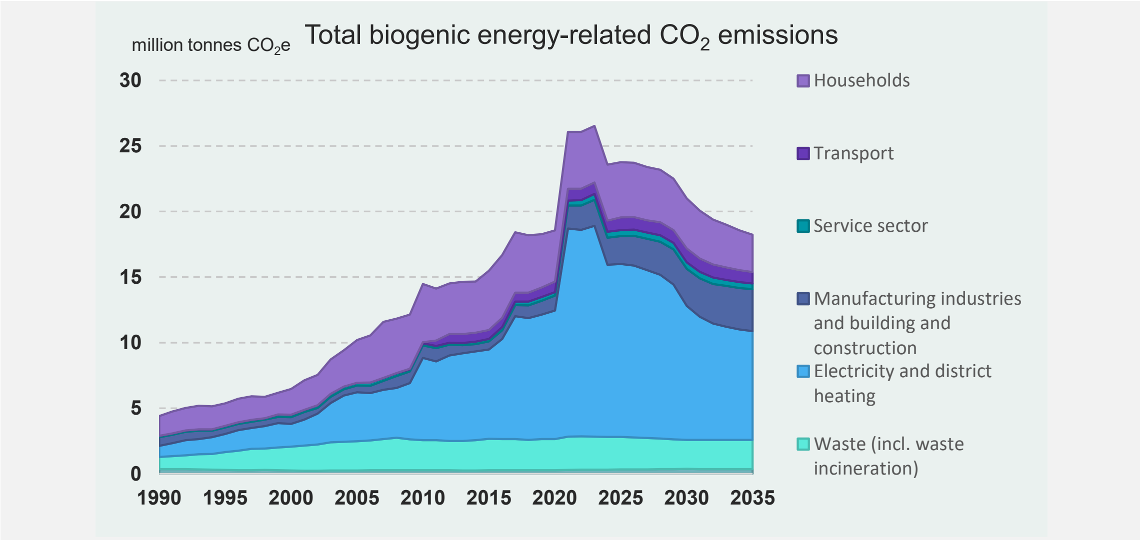
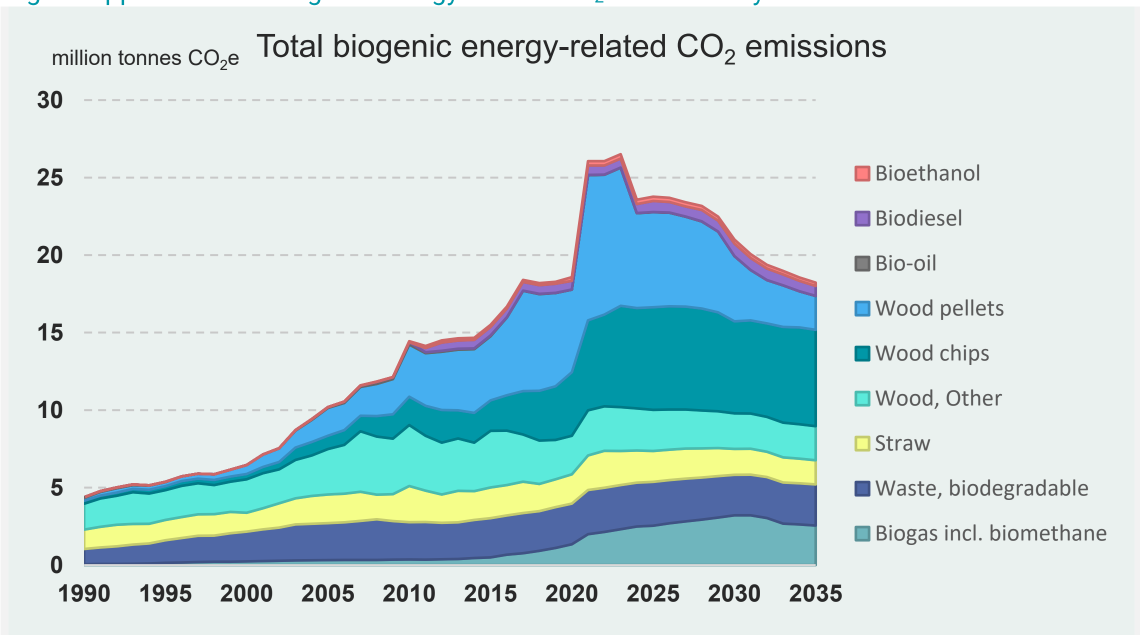


Figure App. 6.2 shows trends in and the composition of biogenic energy-related CO_2 emissions by fuel. As illustrated by the figure, most of the biogenic energy-related CO_2 emissions stem from wood in the form of wood chips, wood pellets and other timber. The biogenic energy-related CO_2 emissions from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

Figure App. 6.2: 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 and biofuels.

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 what 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 (excluding LULUCF), households, other business, 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 (e.g. forest 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: Calculation of CO_2 removals and emissions of CO2, CH4 and N2O linked primarily to soil cultivation in agriculture and forestry activities in the LULUCF sector (*Land Use, Land Use Change and Forestry*).

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.

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

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

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: Terawatt-hour

RE: Renewable energy

Appendix 8: References

Each CSO22 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 CSO22 material. See Appendix 2 for a list of CSO22 sector memoranda and memoranda on assumptions.

Agreement on a green transition of the agricultural sector (*Aftale om grøn omstilling af landbruget*): https://fvm.dk/landbrug/aftale-om-groen-omstilling-af-landbruget/

The "Denmark Forward" 2035 infrastructure plan agreement (*Aftale om infrastrukturplan 2035*) 28 June 2021: https://www.trm.dk/politiske-aftaler/2021/aftale-om-infrastrukturplan-2035-aftale/

Agreement on regulation of the EV charging market (*Aftale om regulering af ladestandermarkedet*) 28 October 2021: https://www.trm.dk/politiske-aftaler/2021/aftale-om-regulering-af-ladestandermarkedet/

Green transport pool realisation agreement (*Aftale om Udmøntning af pulje til grøn transport*) 25 June 2021: https://www.trm.dk/politiske-aftaler/2021/aftale-om-udmoentning-af-pulje-til-groen-transport/

PtX Strategy (*Aftale om udvikling og fremme af brint og grønne brændstoffer (PtX-strategien)*) 15 March 2022: https://www.regeringen.dk/aktuelt/publikationer-og-aftaletekster/aftale-om-udvikling-og-fremme-af-brint-og-groenne-braendstoffer/

Statistics Denmark, Statbank Denmark a): FOLK1A: Population at the first day of the quarter by region, sex, age and marital status.

Statistics Denmark, Statbank Denmark b): BOL101: Dwellings by region, type of resident, use and time.

Denmark can do more (Danmark kan mere II): https://www.regeringen.dk/aktuelt/publikationer-og-aftaletekster/danmark-kan-mere-ii/

EU regulations on CO_2 emissions (EU):
2019/631: https://eur-lex.europa.eu/legal-content/DA/TXT/?uri=CELEX:32019R0631
2019/1242: https://eur-lex.europa.eu/legal-content/DA/TXT/?uri=CELEX:32019R1242

2022 Finance Act (*Finanslov 2022*): https://fm.dk/media/25335/aftale-om-finansloven-for-2022.pdf

Bill to amend the Climate Act (indicative climate target for 2025) (*Forslag til Lov om ændring af lov om klima (Indikativt klimamål for 2025)*): https://www.ft.dk/samling/20211/lovforslag/l31/index.htm

Ministry of Climate, Energy and Utilities: analysis concluding that Denmark is on track to over-achieving the EU requirement for energy by 27% (*Danmark sparer på energien og står til at opfylde EU's krav om energibesparelser med 127 pct*) https://kefm.dk/Media/C/4/Minianalyse%20-%20Energieffektivisering.pdf

2020 climate agreement for energy and industry, etc. *(Klimaaftale for energi og industri mv. 2020 af 22. juni 2020*): (https://www.regeringen.dk/publikationer-og-aftaletekster/klimaaftale-for-energi-og-industri-mv-2020/)

Climate Act and explanatory notes (*Klimalov og bemærkninger til lovforslaget*): https://www.ft.dk/samling/20191/lovforslag/L117/index.htm.

Climate plan for a green waste sector and circular economy (*Klimaplan for grøn affaldssektor og cirkulær økonomi af 16. juni 2020*): (https://www.regeringen.dk/media/9591/aftaletekst.pdf)