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Analysis of the emission reduction contributions of Danish municipalities towards meeting the 70% target by 2030

DK2020

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Prepared for CONCITO and Realdania

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Abbreviations

CO_2e: Carbon dioxide equivalents is a metric measure used to standardise the climate effects of various greenhouse gases.
GHG: Greenhouse gas.
PtX: Power-to-X. The production of liquid or gaseous fuels from electricity.
CCS: Carbon capture and storage.
CCU: Carbon capture and utilization. The process of capturing CO_2 to be used later for a specific use, such as the production of PtX fuels.
BaU: Business as usual.
DECO19 and DECO20: Denmark's Energy and Climate Outlook reports for the years 2019 and 2020. Prepared each year by the Danish Energy Agency. From 2021, replaced by Denmark's Climate Status and Outlook report (CSO21).
CSO21 and CSO22: Denmark's Climate Status and Outlook reports for the years 2021 and 2022. Prepared each year by the Danish Energy Agency.
KPI: Key performance indicator.
RE: Renewable energy.

Disclaimers

CO_2/CO_2e: CO_2 in this analysis refers to CO_2 equivalents.
Separators *in figures*: Full stops are used as thousand separators. Commas are used as decimal points.

List of figures and tables

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1. Summary

Danish municipalities are working to advance the energy and climate agenda through the DK2020 project. The objective of DK2020 is to provide a common framework for Danish municipalities to develop climate action plans in accordance with the Paris Agreement.

This report maps the climate action plans of the 20 pilot municipalities in the DK2020 project. The pilot municipalities represent almost a quarter of the Danish population, and almost one-fifth of the total area of Denmark and of total Danish greenhouse gas emissions. The last climate action plans of the pilot municipalities were approved in spring 2021.

What targets have the pilot municipalities set?
Most of the pilot municipalities have set a target to reduce emissions by 70% by 2030 relative to the 1990 level. Thus, they follow the Danish national emission reduction target. Three of the municipalities have set targets higher than 70%, while one municipality has set a lower target. The combined targets of the pilot municipalities correspond to a 56% reduction in emissions from 2018 to 2030. This is in line with Denmark's national 70% target, which requires emissions to be reduced by 55% from 2018 to 2030. The targets set by the pilot municipalities correspond to reducing emissions to 4.3 million tonnes by 2030, compared to 9.7 million tonnes in the baseline year 2018.

What reductions will be achieved according to the reduction pathways?
If all reductions in the Business-as-Usual (BaU) scenarios are added together, it means the pilot municipalities will reduce emissions to 7.8 million tonnes in 2030 and 6.8 million tonnes in 2050. If the reductions in the municipalities' ambitious scenarios are included as well, emissions will be reduced to 4.9 million tonnes CO_2 in 2030 and 3.4 million tonnes CO_2 in 2050. The ambitious scenarios assume implementation of actions and initiatives set in the pilot municipalities' DK2020 plans.

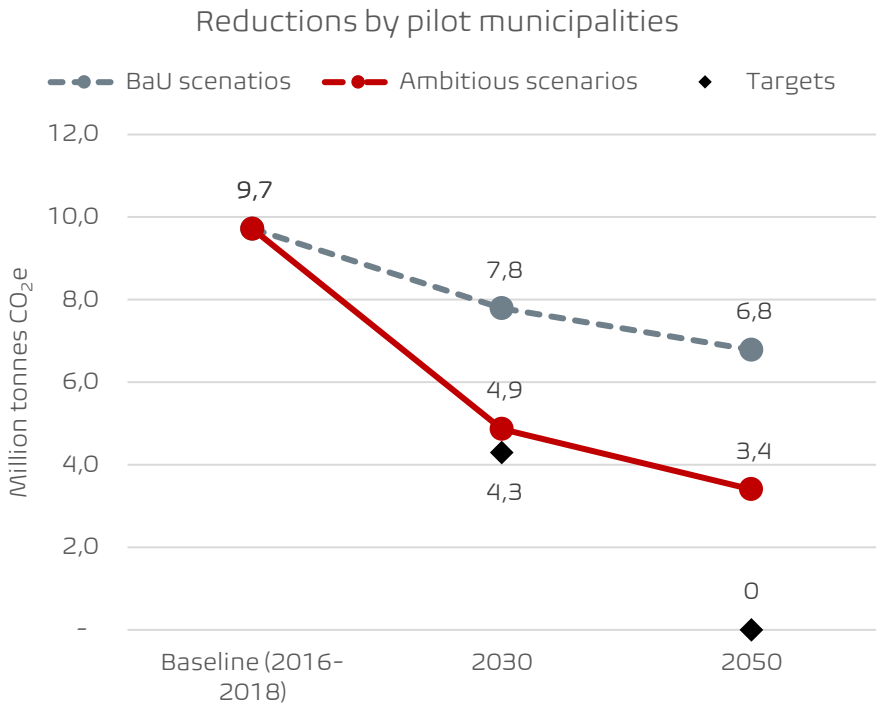

Figure 6: Targets and reductions by pilot municipalities, in total

According to the ambitious scenarios, the pilot municipalities will therefore achieve a reduction of almost 50% (down to 4.9 million tonnes), which is very close to their target of 56% (down to 4.3 million tonnes).

Which initiatives are most effective?

The pilot municipalities have a total of 64 different categories of initiatives, which include all sectors.. The pilot municipalities' initiatives contribute the most to reducing the emissions in the energy sector, where emissions will be reduced by 98%. With regard to the remaining sectors, emissions will be reduced by 23% in the transport sector, 47% in the industry sector, 30% in the agriculture and land use sector and 21% in the 'Other' sector.

In the energy sector, the pilot municipalities will achieve large reductions through deployment of wind and solar energy, conversion from gas- and oil-fired boilers to individual heat pumps, expansion of the district heating network, and energy-efficiency improvements. In the transport sector, the most important reductions will be from electrification of cars and public transport, which will be underpinned by plans and strategies for the deployment of charging stations. The pilot municipalities will also focus on promoting cycling, public transport, densification of station areas, etc.

Regarding the agriculture and land use sector, the pilot municipalities have identified gasification of livestock manure, changing cultivation techniques and crops, setting aside organogenic land, and afforestation as the largest reduction initiatives. In the industry sector, the pilot municipalities have identified electrification, transitioning to green fuels and efficiency improvements.

What reductions will be we achieved if the climate action plans of the 20 pilot municipalities are scaled up to all of Denmark?

If we scale up efforts by pilot municipalities to national level based on CO_2 reductions by each individual sector, then the total CO_2 reductions achieved will be lower relatively speaking. This is due to differences in the sectoral distribution of emissions across pilot municipalities and nationally. If all municipalities match the pilot municipalities' level of climate action, Denmark will reduce its CO_2 emissions to 27.1 million tonnes by 2030. This corresponds to a reduction of 46% nationally, as opposed to a reduction of 50% by the pilot municipalities alone. Thus, there will be a 9-percentage-point gap relative to 2018 towards meeting the national 70% target if all Danish municipalities follow the lead of the pilot municipalities. However, the pilot municipalities have identified initiatives that will bring them further than outlined in Denmark's Energy and Climate Outlook report for 2020 (DECO20) and also further than outlined in the most recent report, Denmark's Climate Status and Outlook 2022 (CSO22). It is also important to note that the pilot municipalities prepared their plans in 2020 and the plans therefore do not capture the effect of the political agreements on CCS, PtX and agriculture, as these were not agreed upon until later.

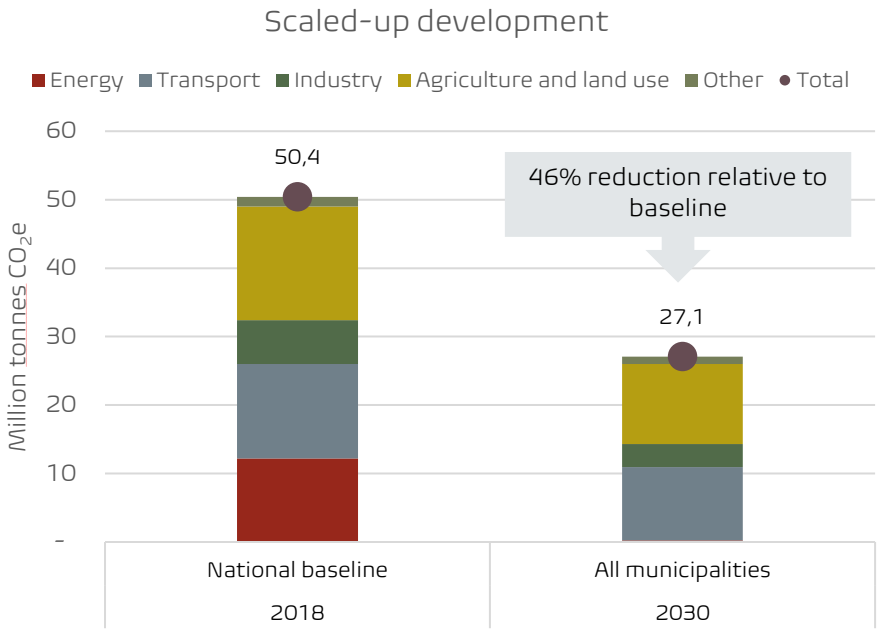

Figure 8: Results of the scale-up analysis, in which the sector reductions in the pilot municipalities' ambitious scenarios have been transferred to the national baseline (2018)

2. Introduction

The consequences of decades of significant emissions of greenhouse gases are now being felt globally in the form of increased temperatures, elevated water levels and deteriorating biodiversity, etc. In 2015, 196 countries, including Denmark, signed the Paris Agreement. The Paris Agreement obligates the parties to prevent global warming by keeping the global temperature rise below 2°C and pursuing efforts to limit the rise to 1.5°C. If Denmark is to meet the targets set and contribute its share to mitigating climate change, initiatives are needed at national, regional as well as municipal level.

A broad coalition of political parties in the Danish Parliament adopted a Danish climate law in 2020, known as the Climate Act. The objective of the Climate Act is to ensure Denmark reduces its greenhouse gas emissions by 70% by 2030 compared to the 1990 level and becomes climate neutral no later than 2050. The Climate Act was later followed by several political agreements regarding energy, waste, carbon capture and PtX fuels.

Danish municipalities are working with the energy and climate agenda through the DK2020 project. The objective of DK2020 is to provide a common framework for Danish municipalities to develop climate action plans in accordance with the Paris Agreement. The end goal of the DK2020 plans is

carbon neutrality by 2050. As part of DK2020, the pilot municipalities will therefore set ambitious goals and milestones to underpin the long-term target of carbon neutrality. For this reason, most of the pilot municipalities have set 2030 targets following the national Climate Act. Realdania, CONCITO, C40 Cities, Local Government Denmark and Danish Regions are providing consultancy to municipalities and are responsible for approving municipal climate action plans. A total of 95 out of the98 Danish municipalities have joined the project. The first 20 of the 95 municipalities - the pilot municipalities - finalised their climate action plans in 2020 (a few of them in the beginning of 2021), while the remaining 75 municipalities are currently preparing their climate action plans. For the first round of municipalities, the process started in November 2020 and will end in September 2022. For the second round of municipalities, the process started in autumn 2021 and will end in 2023.

This report maps the climate action plans of the 20 pilot municipalities. The most recent of these climate action plans were adopted in April 2021. The report addresses the following questions:

- What targets have the pilot municipalities set?
- What emissions reductions are to be achieved by the pilot municipalities in the different reduction pathways?
- Which initiatives are most effective?
- How far will we get if the climate action plans of the 20 pilot municipalities' combined emissions reductions are scaled up to all of Denmark?

The objective is to map the targets and climate action initiatives planned by the pilot municipalities, and how their combined contributions will help realise the national 70% target for 2030. Furthermore, the objective is to examine what specific initiatives the municipalities are planning. This can provide inspiration for the next 75 municipalities preparing their climate action plans.

3. Description of pilot municipalities

The climate action plans of the 20 pilot municipalities have been certified by C40 Cities on the basis of the Climate Action Planning Framework (CAPF). The pilot municipalities were selected by CONCITO and Realdania as representative of Danish municipalities in general based on geographical distribution and a fair representation of both urban and rural municipalities, municipalities with and without industry, etc.

Furthermore, CONCITO and Realdania have aimed to include municipalities that have been working with energy and climate action planning for several years as well as municipalities that are relatively new to this work.

The 20 pilot municipalities are:

- Aarhus
- Albertslund
- Allerød
- Assens
- Fredericia
- Frederiksberg
- Frederikshavn
- Helsingør
- Høje Taastrup
- Jammerbugt
- Køge
- Lejre
- Lemvig
- Lolland
- Middelfart
- Randers
- Roskilde
- Samsø
- Sønderborg
- Vejle

Figure 1: Geographical spread of the 20 pilot municipalities

The pilot municipalities represent almost a quarter of the Danish population, and almost one-fifth of the total area of Denmark and of total Danish greenhouse gas emissions[1]. See Appendix 1 for a more detailed table comparing pilot municipalities with the whole of Denmark based on agricultural land area, sector emissions, emissions per capita, and more.

Pilot municipalities	Percentage share of 'the whole of Denmark'
Number of municipalities	20%
Population	24%
Area	18%
Greenhouse gas emissions	19%

Table 3: The pilot municipalities compared with Denmark as a whole

Total greenhouse gas emissions by the pilot municipalities came to just short of 10 million tonnes in the baseline year, which for most of the pilot municipalities is 2018.

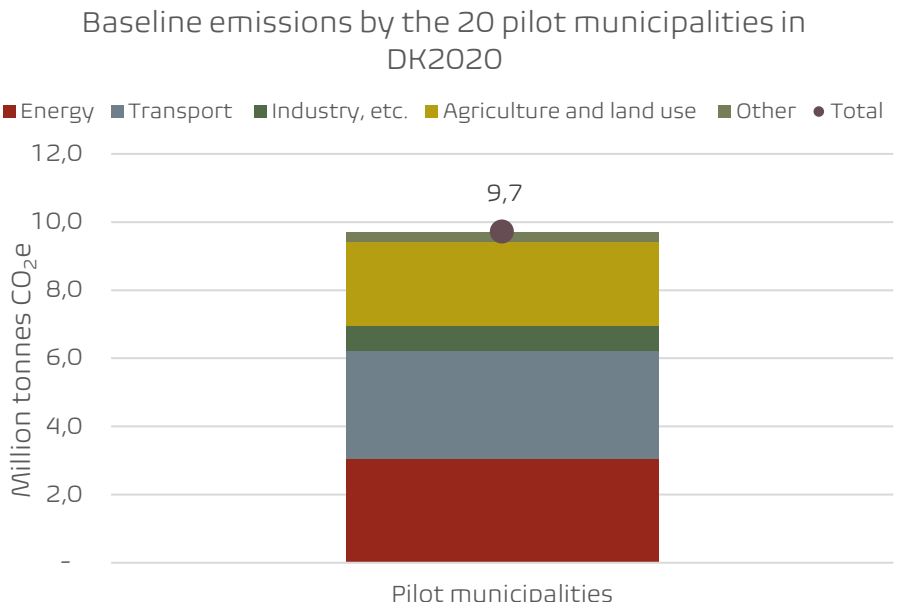

Figure 2: Total greenhouse gas emissions by the 20 pilot municipalities, million tonnes CO_2 equivalents. For most of the municipalities, the baseline year is 2018 (some municipalities, however, use 2016 or 2017). See Appendix 2 for a detailed description of baseline year emissions by the 20 municipalities

[1] Total Danish greenhouse gas emissions for 2018 were estimated at 50.4 million tonnes CO_2 equivalents in Denmark's Climate Status and Outlook 2021. The report was prepared by the Danish Energy Agency. The estimate does not include emissions linked to the North Sea and carbon removals by existing forests.

Compared with the breakdown of total Danish greenhouse gas emissions, in the breakdown of emissions by the 20 pilot municipalities, energy and transport account for a relatively larger share, while agriculture and industry account for a smaller share than at national level. The figure below shows the breakdown of emissions by sectors.

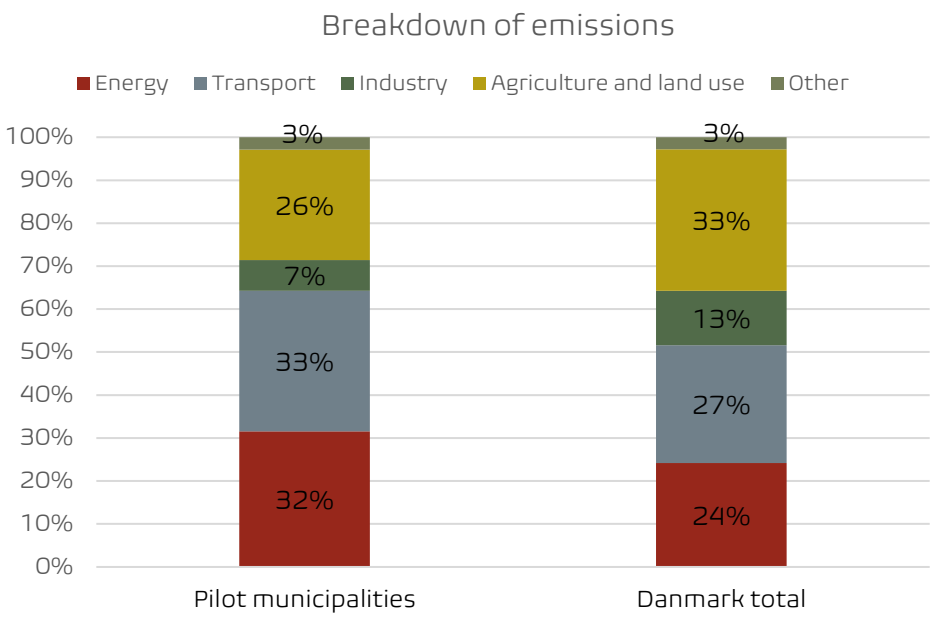

Figure 3: Total emissions by sector for the pilot municipalities and for the whole of Denmark, respectively

Data used for the mapping

This mapping has been prepared on the basis of data from the climate action plans of the 20 pilot municipalities, as well as from their catalogues of initiatives and underlying scenarios. DK2020 allows the municipalities a high degree of freedom with regard to method and calculations. However, the municipalities must complete the same documentation form - the CAPF form - which ensures a common framework for approving climate action plans. This freedom of methodology allows municipalities to include their own context, resources and desired action areas, but it also means that there may be methodological differences that make direct comparisons between municipalities difficult. For example, some municipalities include air transport, while others do not.

The combined targets of all pilot municipalities

The pilot municipalities' intermediate targets for 2030

The target of a 70% reduction by 2030 set in the Danish Climate Act is relative to emissions in 1990. In line with this, most of the municipalities have chosen to set out targets for 2030 relative to 1990[2]. Table 2 lists the 2030 targets of the 20 pilot municipalities. In many cases, the municipalities use the 2030 targets as drivers for their climate action plans.

The reduction targets of pilot municipalities by 2030, relative to 1990	Number of municipalities
55%	1
70%	16
85%	1
100%	2*

Table 2: List of 2030 targets set by the 20 pilot municipalities.
**For one municipality, this target applies only to energy and transport*

The majority of the pilot municipalities have chosen to follow the lead of the national 70% target. A couple of municipalities have set a more ambitious target, while a single municipality has set a slightly less ambitious target.

The DK2020 project does not advise a clear method for the best way to transfer the 70% target to a municipal context. A challenge in this regard is that emissions in the individual municipality distribute differently across sectors than is the case at national level, which means the leeway and possibility for achieving reductions differ from municipality to municipality. Thus, there is no simple way to interpret whether the level of ambition of an individual municipality is more ambitious or less ambitious than the national 70% target. For example, an urban municipality, in which the majority of emissions come from energy and transport, could achieve far more reductions than a rural municipality with large emissions from agriculture.

If we sum up the 2030 targets of the pilot municipalities, they will contribute a 56% reduction relative to baseline emissions (i.e. primarily 2018 emissions), and a combined target to reduce emissions to below 4.3 million tonnes CO_2 equivalents by 2030.

[2] Some pilot municipalities have not set 2030 targets relative to 1990 but relative to their baseline year. In these cases, we have projected backwards, using national development factors, to make comparison with other municipalities possible.

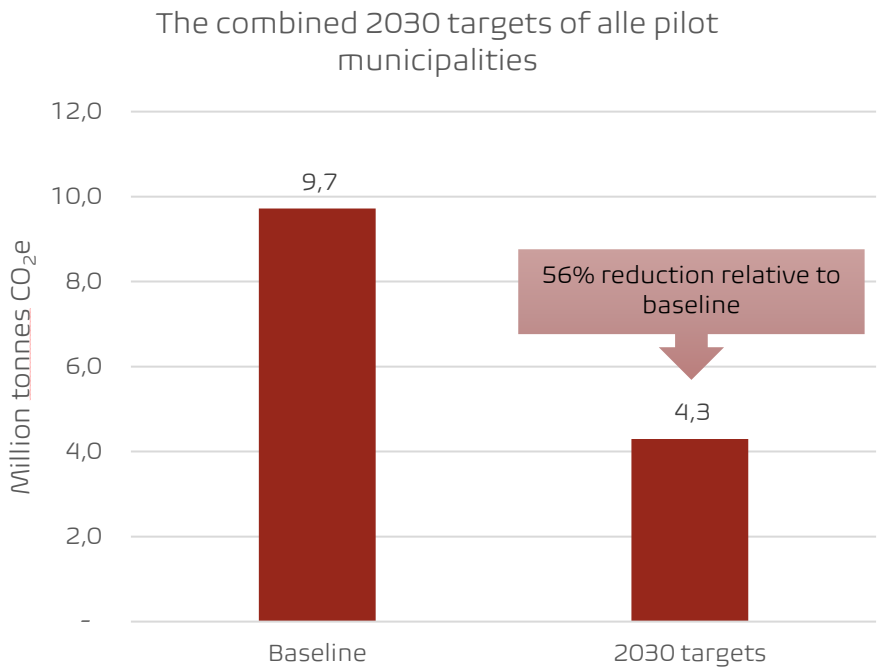

Figure 4: The combined 2030 targets of all pilot municipalities

The national 70% reduction in the Danish Climate Act translates to a 55% reduction by 2030, relative to 2018. Taken together, the pilot municipalities aim to reduce emissions by 56% relative to their baseline year (i.e. primarily 2018), and they therefore have approximately the same level of ambition as prescribed in the Climate Act.

4. Reduction contributions by pilot municipalities

As part of the DK2020 project, the pilot municipalities have performed a scenario analysis in which they set out reduction pathways to realise their climate targets. The municipalities have used scenarios and reduction pathways to examine and quantify all the actions and instruments they want to prioritise and implement in the years to come.

Because the municipalities have the freedom of methodology to prepare their climate action plans, the number and content of scenarios vary significantly from municipality to municipality. In this analysis, we focus on two types of scenario prepared by all of the pilot municipalities:

- **BaU scenarios:** Although there may be differences in their methodological approach to BaU scenarios, the municipalities generally assume a BaU scenario in which they lead a ***passive*** energy and climate policy.

- **Ambitious scenarios:** A scenario in which the municipality and local partners lead a ***proactive*** energy and climate policy beyond the national framework conditions. If municipalities have more than one scenario above the BaU scenario, we have included their most ambitious scenario in the analysis.

In both the BaU scenarios and the ambitious scenarios, the municipalities assume the national electricity system is green. This is therefore a key prerequisite for pilot municipalities to realise their targets. Appendix 3 contains a more detailed description of the methodological approach of the pilot municipalities in their preparation of BaU and ambitious scenarios.

If all reductions in the BaU scenarios are added together, it means the pilot municipalities will cut emissions to 7.8 million tonnes in 2030 and 6.8 million tonnes in 2050. If the reductions in the municipalities' ambitious scenarios are included as well, emissions will be reduced to 4.9 million tonnes CO_2 in 2030 and 3.4 million tonnes CO_2 in 2050. The ambitious scenarios assume implementation of actions and initiatives set out in the DK2020 plans.

Million tonnes CO_2 equivalents	2030	2050
BaU scenarios	7.8	6.8
Ambitious scenarios	4.9	3.4
Targets	4.3	0
Emissions gap	*0.6*	*3.4*

Table 3: Reduction contributions by pilot municipalities in BaU and ambitious scenarios in 2030 and 2050, respectively

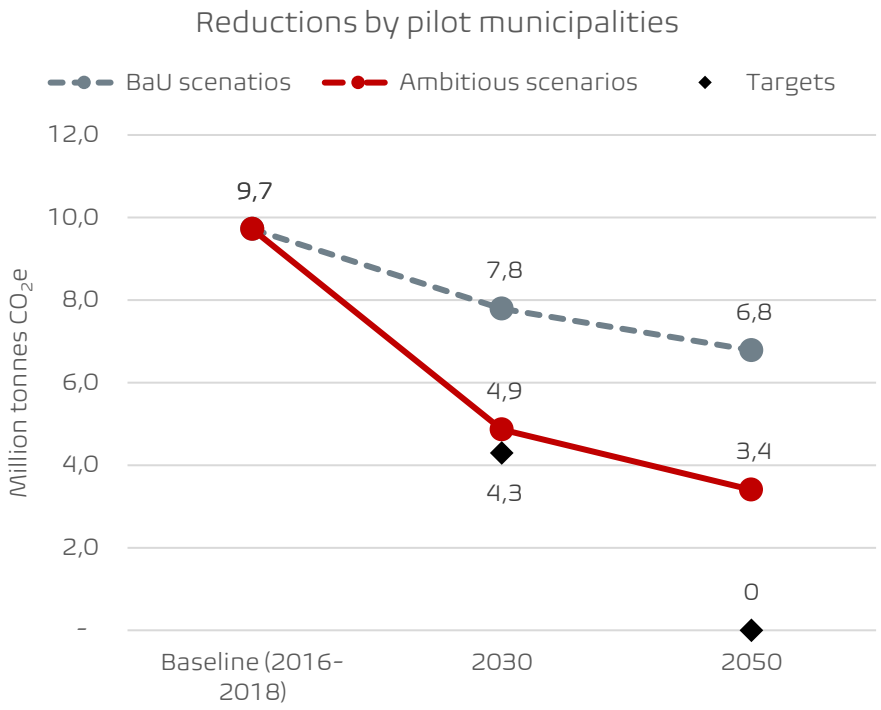

Figure 5: Targets and emission reductions by pilot municipalities, in total

According to the ambitious scenarios, the pilot municipalities will therefore achieve a reduction of around 50% (down to 4.9 million tonnes), which is only slightly shy of their target of 56% (down to 4.3 million tonnes).

Thus, the pilot municipalities have identified the majority of the instruments and initiatives needed to realise their short-term targets. In this connection, note that the pilot municipalities prepared their climate action plans before a number of political energy and climate agreements were concluded (the agreements on a green transition of the agricultural sector, on PtX and on CCS, for example). Therefore, the pilot municipalities did not know all of the national framework conditions for some sectors. It is therefore likely that the pilot municipalities will be able to plan even larger reductions when they

revise their climate action plans in the years to come (CAPF requires climate action plans to be revised at least once every five years).

In the most ambitious scenarios, the pilot municipalities still have an emissions gap of 3.2 million tonnes towards realising the long-term goal of carbon neutrality by 2050. This is because they do not know which initiatives will be prioritised at national level in the long term, which makes it more difficult to identify long-term reduction potentials.

Sector emission reductions

The table below shows the sector breakdown of the total reduction contribution of 4.8 million tonnes CO_2 equivalents by 2030. The table shows that the energy sector (electricity and heating) in total for all pilot municipalities will have to reduce emissions to almost zero by 2030, while both the transport sector and the agricultural sector will have to contribute reductions of 0.7 million tonnes CO_2 equivalents. The sector reductions are used as input for the scale-up analysis.

	Baseline (million tonnes CO_2)	2030 (million tonnes CO_2)	Reduction (million tonnes CO_2)	Reduction (%)
Energy	3.1	0.1	3.0	98%
Transport	3.2	2.5	0.7	23%
Industry, etc.	0.7	0.4	0.3	47%
Agriculture and land use	2.5	1.8	0.7	30%
Other	0.3	0.2	0.1	21%
Total	9.7	4.9	4.8	50%

Table 4: Total 2030 sector reductions by pilot municipalities, according to the municipalities' ambitious scenarios

As mentioned above, we still do not know the full pathway to realising the 70% target nationally, and therefore we do not know the precise reductions and targets required of individual sectors. The government's Climate Programme 2021 (Danish government, 2021) presents a proposal for how Denmark as a whole will realise the target. For the programme, the Danish Energy Agency analysed four pathways to realising the short-term 2030 target and the long-term 2050 target of carbon neutrality.

The government's Climate Programme provides a perspective on the total national contributions needed by the individual sectors, and it is relevant to compare these contributions to the pilot municipalities' expected contributions.

The following contributions are required under all four pathways in the Climate Programme:

- Energy emissions reduced by close to 100%
- Transport emissions reduced by at least 35%
- Agriculture emissions reduced by 20-40%, depending on the pathway in question
- Industry emissions reduced by at least 55%
- Emissions from the category 'Other' reduced by at least 50%

All together the above sum up to a 55% reduction in 2030 relative to 2018; corresponding to 70% relative to 1990.

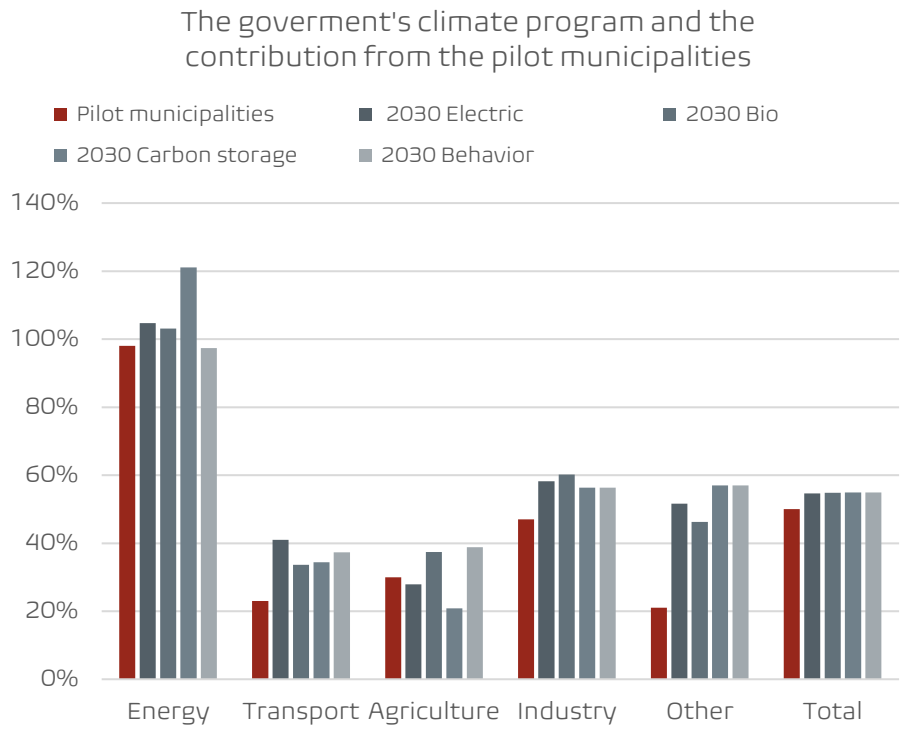

Figure 6: Reduction percentages by sector in 2030 relative to 2018 in the four pathways presented in the government's Climate Programme 2021 (grey columns), and municipal sector reductions (red column). See Appendix 4 for a detailed description of the scenarios in the government's Climate Programme 2021

Pilot municipalities will reduce emissions by 50% by 2030:

- The energy sector is keeping good pace: green electricity, phase-out of oil and gas for space heating, and conversion of district heating production are all well-known instruments identified by the pilot municipalities.
- The transport sector is lagging somewhat behind: the pilot municipalities are well on their way with initiatives on electric cars but are having difficulty identifying specific instruments and reductions for heavy-duty transport. This is to be expected, because the national and international framework conditions for this sector are uncertain.
- The agriculture and land-use sector is keeping good pace: even before the pilot municipalities knew which instruments would be prioritised nationally. Afforestation, in particular, is a major contributor.
- The industry sector is keeping good pace: However, not all the municipalities have industry baseline emissions. Those that have, choose to focus on the sector through partnerships with the largest emission contributors.
- The 'Other' sector is lagging somewhat behind: This sector covers all of the emissions not included in other sectors, for example landfills and F gases. ‘Other’ accounts for just under 5% of the pilot municipalities’ emissions in the baseline year and the municipalities generally have had difficulty identifying reduction instruments, because these are primarily regulated through national framework conditions.

Reduction initiatives

In their climate action plans, municipalities identify unique instruments and initiatives under each sector, for example EV recharging infrastructure and deployment of district heating. This mapping of the energy and climate action initiatives of the 20 municipalities distinguishes between initiatives for which a reduction effect has been calculated, and initiatives the effect of which has been described qualitatively.

Our analysis shows that the pilot municipalities have 64 different types of reduction initiatives. Altogether, the 20 pilot municipalities have planned a total of 446 initiatives to be implemented as part of their climate action plans.

The table below shows the reduction potential for a number of categories of initiative. We have divided the initiatives into categories for the sake of simplicity. For example, the category 'Renewable electricity production' covers initiatives concerning onshore and nearshore wind turbines, as well as roof-mounted and ground-mounted solar PV systems.

Category of initiative	Reduction potential (kt CO_2e)
Renewable electricity production	544
Electric cars	389
Conversion of individual heat sources	322
Biogas (replacing natural gas and reducing emissions from manure management)	274
Conversion of district heating production (without waste initiatives)	229
Changes to agricultural production	210
Separation of plastic and other waste fractions	136
Heat savings	127
Afforestation	114
Set-aside of organogenic land	103
Industry conversion	101
Changes in transport habits	60
Carbon capture and storage	41
Conversion of heavy-duty transport and public transport	21

Table 5: Twelve selected categories of initiatives and total reduction potentials calculated by the 20 pilot municipalities. Note: The effect of some initiatives overlaps, and for some initiatives the effect diminishes up to 2030 (for example, the effect of renewable electricity production and energy savings). Furthermore, not all of the 20 pilot municipalities have calculated CO_2 reductions for all of their specific initiatives. The reduction potentials can therefore not be directly compared with total scenario reductions

The analysis shows that pilot municipalities focus in particular on the electricity and district heating sectors, which they expect will contribute most to reductions. In these sectors, the pilot municipalities are working proactively to increase wind and solar power capacity, expand the district heating network, convert district heating production to biomass or heat pumps, and improve the energy efficiency of buildings to reduce electricity and heating consumption. Note that the pilot municipalities assume the national electricity system will be green by 2030, and any local deployment of wind and solar power will therefore not have a direct reduction effect in the scenario approach. Many of the pilot municipalities instead indicate the reduction potential using the electricity emission factor in their baseline year.

The transport sector is another focus area among the pilot municipalities. Initiatives here include unique initiatives with a large reduction effect such as deployment of electric cars and conversion of heavy-duty transport and public transport. The pilot municipalities also have targeted initiatives and instruments to reduce private transport beyond what is expected in national projections. Three municipalities identify a potential for the production of alternative fuels through PtX for use in heavy-duty transport, for example.

Within agriculture and land use, pilot municipalities focus in particular on gasification of livestock manure, changes to cultivation techniques, change of crops and increased use of catch crops, reduced meat production, set-aside of organogenic/carbon-rich soils, and afforestation.

With regard to the industry sector, emphasis is on transitioning to green fuels, but also on energy efficiency improvements in general, as well as on using recycled materials in production.

Transition indicators (KPIs)

The table below shows pilot municipality targets broken down by six transition indicators (KPIs). The indicators can be compared with each other as well as with national expectations.

- Phasing out natural gas for space heating. This includes converting to another heat source (primarily district heating and heat pumps) and replacing it with sustainable gas
- Increasing the share of electric cars in the total number of passenger cars on the road
- Deploying new solar PV power generation from both ground-mounted and roof-mounted systems
- Deploying new wind turbine power from both onshore and nearshore wind turbines. This primarily includes new onshore wind capacity but a number of municipalities are also working to deploy new nearshore wind capacity (around 20% of energy production in the table below)
- Setting aside organogenic land (both rewetting and extensification)
- Afforestation

Phasing out natural gas for space heating (phase-out percentage)	Electric cars (share of car fleet)	Solar PV (GWh)	Onshore and nearshore wind (GWh)	Setting aside organogenic land (ha)	Afforestation (ha)
100%	35%	-	-	-	1,300
100%	35%	-	-	-	167
80%	45%	56	-	-	21
70%	23%	56	-	786	738
100%	20%	-	-	60	8
100%	40%	22	-	-	-
100%	30%	188	335	170	1,000
100%	20%	-	-	-	-
100%	30%	120	-	50	250
30%	23%	300	-	1,000	500
100%	30%	133	107	-	500
50%	35%	75	75	200	224
50%	35%	250	400	59	500
100%	20%	414	240	-	234
100%	35%	3	-	-	100
100%	25%	43	274	650	3,000
80%	40%	18	3	117	150
100%	30%	-	-	-	-
100%	46%	100	-	294	800
100%	30%	200	200	-	3,000

Table 6: List of selected transition indicators for pilot municipality performance.
** Electricity production from nearshore wind turbines is included in the estimate for onshore wind. Nearshore wind has been estimated for two pilot municipalities and accounts for an overall 19% of onshore wind production*

Pilot municipality targets have been scaled up to allow for comparison between the transition indicators and national expectations. Phasing out natural gas for space heating has been scaled up on the basis of gas consumption in the baseline year by the individual municipality; electric cars have been scaled up on the basis of the population in the individual municipality; and the four remaining indicators have been scaled up on the basis of the agricultural area in the individual municipality.

Indicator	Pilot municipalities	Scaled up to the whole of DK	Compared with national expectations
Phasing out natural gas for space heating	90%	90%	In its *Denmark can do more II* strategy, the government has set a target of 100% green (i.e. renewable) gas by 2030 and accelerated deployment of district heating, so that deployment will be completed by 2028. Not directly comparable, but municipal targets align nicely with national expectations.
Phasing in electric cars	32%	32%	More or less at par with Danish Energy Agency expectations reported in Denmark's Climate Status and Outlook 2022, which projects just under 1 million electric and plug-in hybrid cars by 2030. This is above the level projected by the Danish Energy Agency in Denmark's Energy and Climate Outlook 2020, which is the basis for the municipal climate action plans.
Electricity production from solar PV	1,976 GWh	10,900 GWh	Corresponds to around nine-times the electricity production from solar PV in 2020. *Denmark can do more II* sets a target of 10-times more electricity production based on solar PV[3].
Electricity production from onshore and nearshore wind turbines	1,634 GWh	9,000 GWh	Corresponds to a doubling of electricity production from onshore wind by 2020. Corresponds to the target in *Denmark can do more II*[4].
Setting aside organogenic land	3,386 ha	18,800 ha	Corresponds to around 25% of the target in the agreement on a green transition of the agricultural sector to set aside 80,000 ha[5]. This agreement was concluded after the municipalities submitted their climate action plans.
Afforestation	12,492 ha	69,500 ha	This is more than the national ambition of the forested area of Denmark totalling 20-25% within one tree generation (80-100 years from the time of the decision in 2002, i.e. 2100). This requires planting around 60,000 ha new forest by 2030.

Table 7: Transition indicators scaled up to the whole of Denmark and compared with national expectations

This analysis looks more closely at total gas consumption by pilot municipalities and the total, scaled-up reduction in gas consumption for space heating expected at national level. If the rest of Denmark follows the lead of the pilot municipalities, Danish gas consumption will be reduced by 90%, corresponding to consumption of only 0.9TWh by 2030, compared with 8.7TWh in 2018. The pilot municipalities are particularly ambitious in this regard, given that several agreements to phase-out individual gas-fired boilers were not concluded until after the pilot municipalities submitted their DK2020 climate action plans.

[3] The target has been described as a quadrupling of electricity from solar and onshore wind, but Minister for Climate, Energy and Utilities Dan Jørgensen has announced a distribution key indicating a 10-fold increase in solar electricity and a doubling of onshore wind electricity https://www.berlingske.dk/politik/regeringen-vil-firdoble-maengden-af-stroem-fra-sol-og-vind

[4] See footnote above.

[5] The ambition in the agreement on a green transition of the agricultural sector is to set aside 100,000 ha of organogenic soils by 2030. This figure includes peripheral land. We have assumed approx. 20% is peripheral land, which gives an expected set-aside of 80,000 ha organogenic soils.

Initiatives cutting across municipal borders

DK2020 distinguishes between three sources of emissions, called 'scopes':

- Scope 1 - emissions from energy consumption by buildings, transport and industry inside municipal borders
- Scope 2 - emissions from use of energy from the supply network (electricity, district heating and gas)
- Scope 3 - emissions linked to goods, transport services and waste from local inhabitants. For example, this includes CO_2 emissions from the production of cars imported from abroad

DK2020 requires scopes 1 and 2 emissions to be included in greenhouse gas emissions inventories, along with scopes 1 and 3 emissions from waste generated inside municipal borders. Municipalities are therefore not required to include all scope 3 emissions in their climate action plans, just as foreign emissions linked to imports of goods are also not counted towards the national 70% target.

However, 15 pilot municipalities have decided to lead the way and have included scope 3 initiatives in their climate action plans. Their initiatives include:

- Green procurement agreements (municipality as a company)
- Using sustainable building materials
- Recycling building materials
- Climate-friendly diet and ecology
- Sustainable living
- Circular economy
    - Reducing resource consumption (municipality as a company)
    - Re-use and recycling of waste electronic equipment
    - Re-use and recycling of textiles
- Increased waste separation and materials recycling
- Food waste recycling and reduced food waste
- Requirement for businesses to prepare CO_2 inventories

Furthermore, six municipalities have international flights as an area of focus, although emissions from this activity are not included in their municipal GHG calculations.

5. Scale-up analysis

The scale-up analysis examined the size of the CO_2 emissions reductions by all municipalities in a scenario in which the remaining 78 Danish municipalities contribute with reductions at the same level as the 20 pilot municipalities.

The data was scaled up by linking the data on sector reductions by pilot municipalities (table 4) with the national breakdown of emissions in the baseline year (figure 4).

Sector	**National baseline** (million tonnes CO_2) (2018)	**Sector reductions by pilot municipalities**	**National emissions in 2030** (million tonnes CO_2)
Energy	12.2	98%	0.2
Transport	13.8	23%	10.7
Industry, etc.	6.4	47%	3.4
Agriculture and land use	16.6	30%	11.7
Other	1.4	21%	1.1
In total	***50.4***		**27.1**

Table 8: Results of the scale-up analysis, in which the sector reductions in the pilot municipalities' ambitious scenarios have been transferred to the national baseline (2018)

With this scale-up method, emissions at national level will be reduced to 27.1 million tonnes CO_2 equivalents in 2030 if the 20 pilot municipalities' most ambitious scenarios are transferred to all municipalities in Denmark. This corresponds to a reduction of 23.3 million tonnes and to a 46% reduction relative to the baseline.

The difference between the total reduction of 50% by pilot municipalities and the scaled-up national reduction of 46% is due to differences in the breakdown of baseline emissions in the pilot municipalities and at national level, respectively.

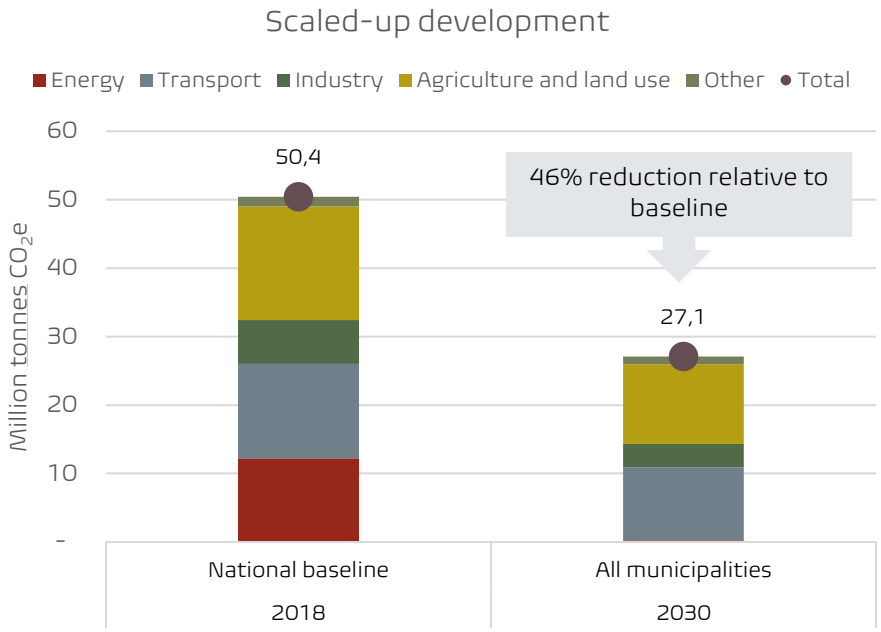

Figure 7: Results of the scale-up analysis, in which the sector reductions in the pilot municipalities' ambitious scenarios have been transferred to the national baseline (2018)

The scaled-up development can be compared with the national 70% reduction target and projections by the Danish Energy Agency. Denmark's Climate Status and Outlook report (previously Denmark's Energy and Climate Outlook) by the Danish Energy Agency provides a best estimate of developments within greenhouse gases at national level as a result of already adopted policies and political agreements. The Danish Energy Agency prepares this report annually, and the most recent report, Denmark's Climate Status and Outlook 2022 (CSO22), was published in April 2022. In CSO22, the Danish Energy Agency assesses that Denmark will reduce emissions to 33.5 million tonnes CO_2 equivalents by 2030. However, the pilot municipalities prepared their climate action plans during 2020 and up until the beginning of 2021 and therefore only had Denmark's Energy and Climate Outlook 2020 (DECO20) at their disposal. In DECO20, the Danish Energy Agency assesses that Denmark will reduce emissions to 43.1 million tonnes CO_2 equivalents by 2030. According to DECO20, Denmark therefore still had an emissions gap of more than 20 million tonnes towards realising the 70% target by 2030.

The municipalities' failure to fully realise the 70% target should therefore be considered against the fact that they prepared their climate action plans during a period when there was still relatively large uncertainty about the national framework conditions. The pilot municipalities, and other

municipalities currently preparing their climate action plans, can build their initiatives and their calculation assumptions on stronger framework conditions. For example, so far, relatively few pilot municipalities have included plans concerning PtX and carbon capture.

It is therefore assessed that the municipalities will be able to achieve more reductions when they revise their plans.

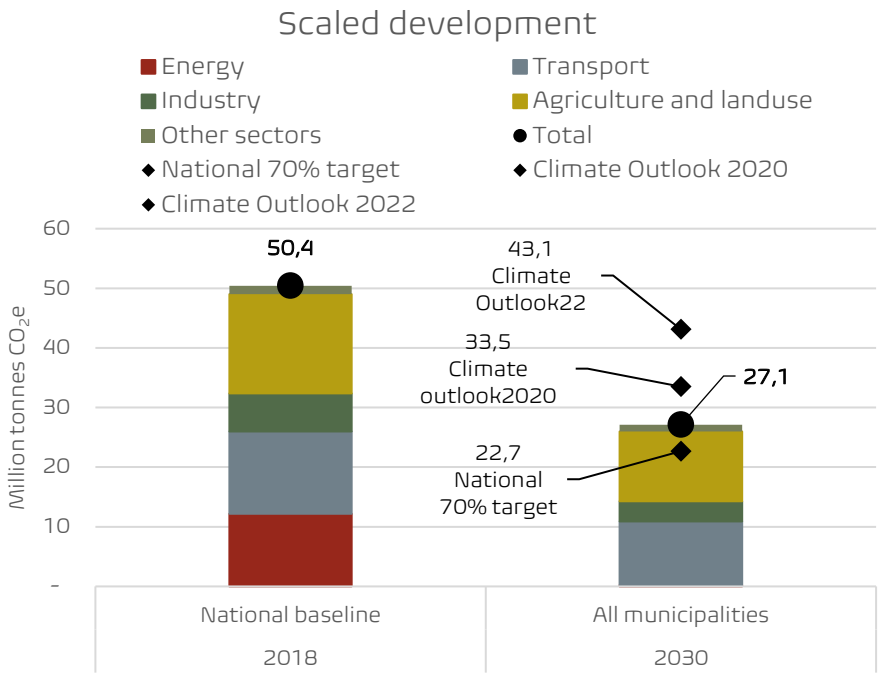

Figure 8: Results of the scaled analysis, as well as emissions according to Denmark's Energy and Climate Outlook 2020 (DECO20), Denmark's Climate Status and Outlook 2022 (CSO22), and the national 70% reduction target

6. Conclusion and perspectives

In general, it can be concluded that:

- The pilot municipalities are ambitious in their plans and have set targets on par with the national target of a 70% reduction in CO_2 emissions by 2030 relative to 1990. Three pilot municipalities have set a target that is higher than the 70% target, while only a single pilot municipality has set a lower target. The combined targets of the pilot municipalities, if realised, correspond to a reduction of 56% by 2030 relative to 2018, which is in line with the 55% reduction needed to realise the 70% target.
- In the pilot municipalities' climate and energy action plans, they identify initiatives that, in total, will give a reduction of 50%. In absolute figures, the pilot municipalities will reduce emissions from 9.7 million to 4.9 million tonnes CO_2 equivalents by 2030. However, to realise their own targets, the pilot municipalities must reduce emissions to 4.3 million tonnes CO_2 equivalents. The pilot municipalities' failure to fully realise the national target of a 70% reduction should be considered against the fact that they prepared their climate action plans in 2020 and the beginning of 2021, when there was still relatively large uncertainty about the national framework conditions.
- If the climate and energy plans of the pilot municipalities are scaled up to Denmark as a whole, this will give a 46% reduction by 2030 relative to 2018.
- Therefore, the pilot municipalities will achieve larger reductions than projected in the Danish Energy Agency's Denmark's Energy and Climate Outlook 2020 (which reflected the framework conditions under which the municipalities prepared their climate action plans) as well as those projected in the Agency's most recent report, Denmark's Climate Status and Outlook 2022.
- In particular, the pilot municipalities are ambitious regarding electric cars and phasing out oil-fired and gas-fired boilers, but also in areas such as afforestation and renewable energy transition to wind and solar energy.

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8. Appendix 1: Comparison of pilot municipalities with Denmark as a whole

	Pilot municipalities under DK2020	Denmark	%
Number of municipalities	20	98	**20%**
Population	1,374,331	5,806,081	**24%**
Area (km^2)	7,725	42,703	**18%**
Agricultural land area (km^2)	4,635	25,784	**18%**
Greenhouse gas emissions (kt CO_2)	9,676	50,400	**19%**
Energy (kt CO_2)	2,959	12,200	**24%**
Transport (kt CO_2)	3,191	13,800	**23%**
Industry, etc. (kt CO_2)	730	6,400	**11%**
Agriculture and land use (kt CO_2)	2,485	16,600	**15%**
Other	307	1,400	**22%**
Total emissions per capita (tonne CO_2/capita)	7.0	8.7	
Total emissions per area (tonne CO_2/km^2)	1,253	1,180	

9. Appendix 2: Greenhouse gas emissions inventories in the baseline year

Baseline year for the Energy and CO_2 inventories of the pilot municipalities

Municipalities in DK2020 are required to prepare greenhouse gas emissions inventories on the basis of a relevant baseline year. The inventory may not be more than four years old when the municipalities submit their climate action plan. The baseline years used by the 20 pilot municipalities are 2016, 2017, 2018 and 2019. The municipalities' approach to the inventories does not differ substantially, but for the 2030 target, only 16 of the 20 pilot municipalities have estimated their total CO_2 emissions for the reference year 1990. Most of the municipalities that have estimated their CO_2 emissions for 1990 have used a simple backwards projection from the baseline year based on the national CO_2 emissions reductions in the period from 1990 until the relevant baseline year. On the basis of this, the estimate of the 1990 level is associated with significant uncertainty, and therefore, in this report, the baseline year is used as the reference year for assessment of the DK2020 efforts by the pilot municipalities.

Assumptions behind baseline CO_2 emissions estimates by pilot municipalities

The calculation methods vary between the 20 pilot municipalities. A fundamental difference in their GHG inventories is how they include and treat CO_2 emissions from air transport. Six pilot municipalities do not include air transport as part of their Energy and CO_2 inventories. Furthermore, for the remainder of the pilot municipalities, some include only domestic flights, while others include both domestic and international flights within Europe. Seven municipalities only include domestic flights, four include international flights, and for the three remaining municipalities it is unclear whether all flights are included.
There is no data per capita for municipal transport habits regarding international flights. Therefore, calculations include either regional or national data distributed between the municipalities based on the number of inhabitants in the municipality.

Generally, the municipalities include local ferry transport and fishing in the inventory of the baseline year.. However, two municipalities, for example, do not include two, local ferry lines.

Baseline emissions

The assumptions underlying the GHG inventories of the pilot municipalities reveal differences in their CO_2 emissions, in particular when broken down by

sector. Figure 10 shows baseline CO_2 emissions by the pilot municipalities, broken down by sector.

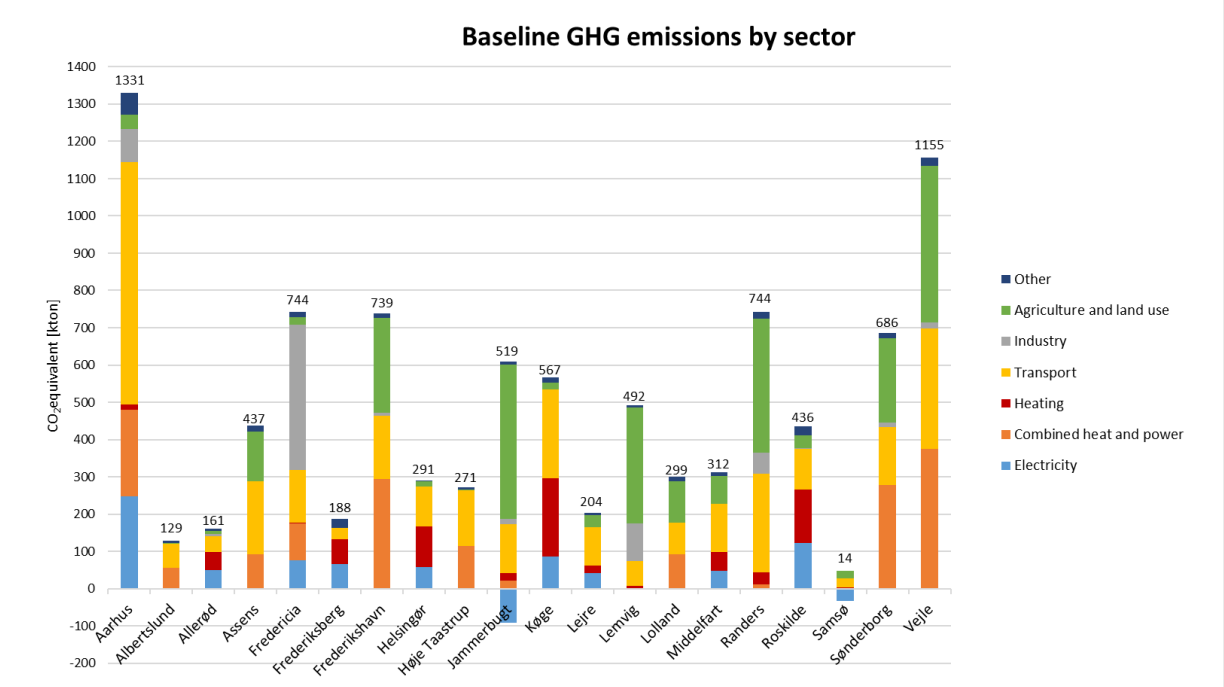

Figure 9 Total baseline CO_2 emissions by pilot municipalities broken down by sector

As mentioned above, it is difficult to see any correlations in CO_2 emissions by sector across all 20 pilot municipalities. This confirms that the pilot municipalities were selected to ensure diversity and representativeness of different types of municipalities in Denmark, for example urban, rural and industry-intensive municipalities.

Total CO_2 emissions by pilot municipalities are around 9.8 million tonnes CO_2 equivalents, which corresponds to around 19% of national baseline emissions in 2018. To make consideration for differences in the municipalities' number of inhabitants, in figure 11 the baseline CO_2 emissions have been calculated per capita.

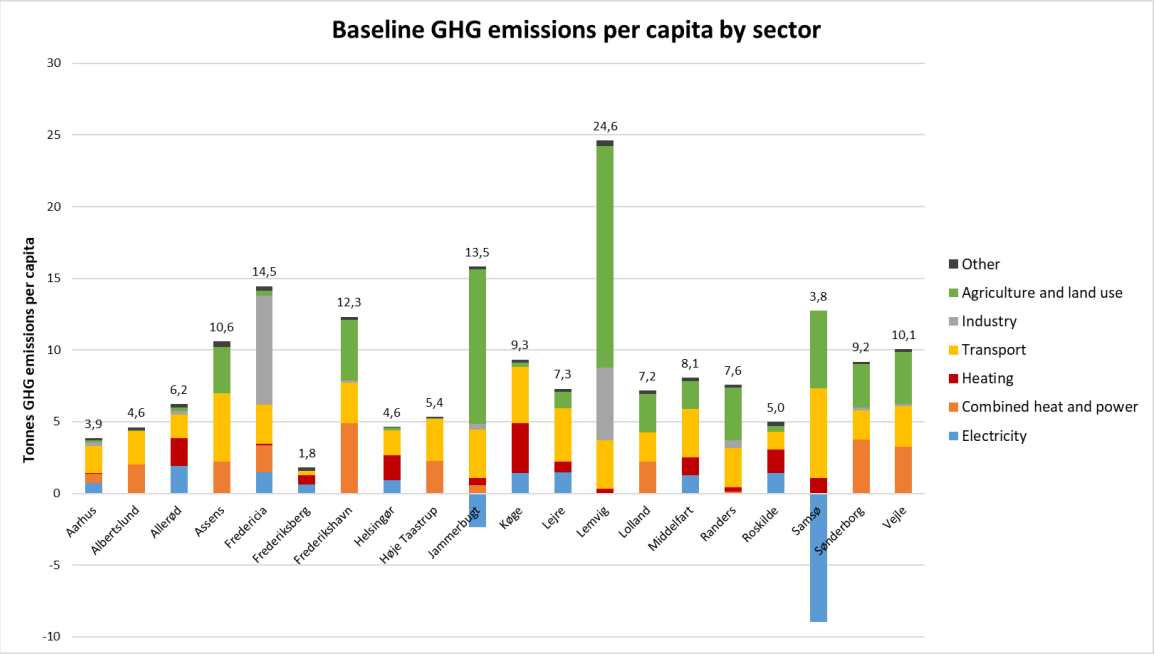

Figure 10 Baseline CO_2 emissions by pilot municipalities per capita, broken down by sector

This report uses the sector classification shown in figures 10 and 11, because this classification is close to that used by the pilot municipalities. However, there are variations in the way the pilot municipalities allocate CO_2 emissions to sectors. This report allocates emissions to sectors as follows:

Sector	Content
Electricity	Calculation and initiatives focussing only on electricity production and electricity consumption.
Combined electricity and heating	Calculation and initiatives focussing on electricity and heat production (CHP) and consumption (energy-efficient buildings, etc.). In some municipalities, this category also covers total energy, which may include process energy.
Heating	Calculation and initiatives focussing only on heat production and consumption.
Transport	Calculation and initiatives for transport and mobility.
Industry	Calculation and initiatives for process energy and industrial processes.
Agriculture and land use	Calculation and initiatives for agricultural practices and land use, such as afforestation, nature restoration, changed cultivation techniques, etc.
Other	Calculation and initiatives for wastewater, landfilling, and chemical processes.

Comparison of baseline CO_2 emissions by pilot municipalities

Figure 10 reveals a general discrepancy between rural and urban municipalities in how CO_2 emissions distribute across sectors. For rural municipalities in general, agriculture and land use accounts for the largest share of emissions.

In 9 of the 20 pilot municipalities, the transport sector accounts for the largest share of emissions. This applies in particular for urban municipalities. In the municipality in which transport accounts for the largest percentage share of emissions, the sector accounts for as much as 54% of the municipality's total CO_2 emissions. For the transport sector, municipalities differ regarding whether they include through-traffic in their GHG inventory or instead include transport by inhabitants, and private and municipal businesses in the municipality.

The industry sector accounts for the largest share of total emissions (52%) in only one municipality, and this is primarily because a large oil refinery is located in the municipality.
12 of the pilot municipalities estimate industry emissions separately, while the remaining eight municipalities divide CO_2 emissions from industry between Energy and Other. There is no clear correlation between the way emissions are allocated and the size of the emissions. This means that the estimate in

this report may slightly underestimate emissions from the industry sector, as the municipalities may have calculated the emissions under other sectors, for example the heating sector. For example, 90% of emissions from one municipality's heating sector in fact come from industry, because this is the way the municipality chose to calculate its emissions. However, this is the exception rather than the rule, as the share in question was a minor element in most other municipalities.

10. Appendix 3: Methodologies and scenarios

Content of the BaU scenario

Generally, the municipalities have used the most recent Energy and Climate Outlook report (today called Denmark's Climate Status and Outlook report) by the Danish Energy Agency as the basis for their BaU scenarios. Denmark's Energy and Climate Outlook (DECO) reports outline a 'frozen-policy' scenario for developments in the Danish energy, transport, industry and agricultural sectors, and remaining sectors, up to 2030, based on existing national legislation and plans.

The most widely used DECO reports by the pilot municipalities are DECO19 and DECO20, which are based on the plans and policies adopted by the Danish Parliament by the end of May 2019 and 2020, respectively. This includes the Energy Agreement of 29 June 2018 (Danish Energy Agency, 2019). It is therefore important to bear in mind that national legislation and plans have changed since the 20 pilot municipalities prepared their climate action plans, and the BaU scenarios for more recent DK2020 municipalities will therefore appear more ambitious.

100% renewables-based electricity production by 2030 is an important assumption in the BaU scenario. This means that DK2020 municipalities cannot estimate a CO_2-reduction potential for deployment of wind and solar energy for 2030.

For the transport sector, 300,000 new cars and vans are expected to be either electric or plug-in hybrids, of which 9% will be vans. This corresponds to 22% of total expected sales of new cars and vans by 2030.

Initiatives concerning agriculture and land use were not widespread before the adoption of the new agricultural agreement on a green transition of the agricultural sector on 4 October 2021, and the BaU scenario does therefore not indicate any significant changes in the agriculture sector.

The climate action plans of the pilot municipalities were prepared at different points in time, and the political agreements included by the municipalities in their BaU scenario therefore vary. For example, note that some municipalities include the decision by the government to cull all mink in Denmark during the covid-19 pandemic, the green road transport agreement, etc.

Some of the pilot municipalities supplement the projections in Denmark's Energy and Climate Outlook with projections and analyses prepared by the Danish Council on Climate Change, the Danish Government's Climate Partnerships or consultancy firms.

The ambitious scenario:

The ambitious scenario includes the 20 pilot municipalities' energy and climate action initiatives beyond the BaU scenario. In other words, this is where the pilot municipalities play a proactive role in realising their 2030 and 2050 targets. Only a single municipality does not distinguish between a BaU scenario and a more ambitious scenario in its climate action plan.

Some municipalities indicate more than one ambitious scenario. For example, a differentiation can be made between a scenario in which the climate action initiatives are financially feasible and practicable and a scenario in which the initiatives require major investments. An example of a cost-intensive initiative is the establishment of CCS facilities at CHP plants or new biogas plants, both of which require major investments.

In this report, the CO_2 reductions of the pilot municipalities have been estimated in a BaU scenario as well as in an ambitious scenario. The ambitious scenario therefore represents all the ambitious scenarios set up by the pilot municipalities. Figure 12 shows total baseline CO_2 emissions by pilot municipalities and their CO_2 reductions in the BaU scenario and the ambitious scenario, respectively.

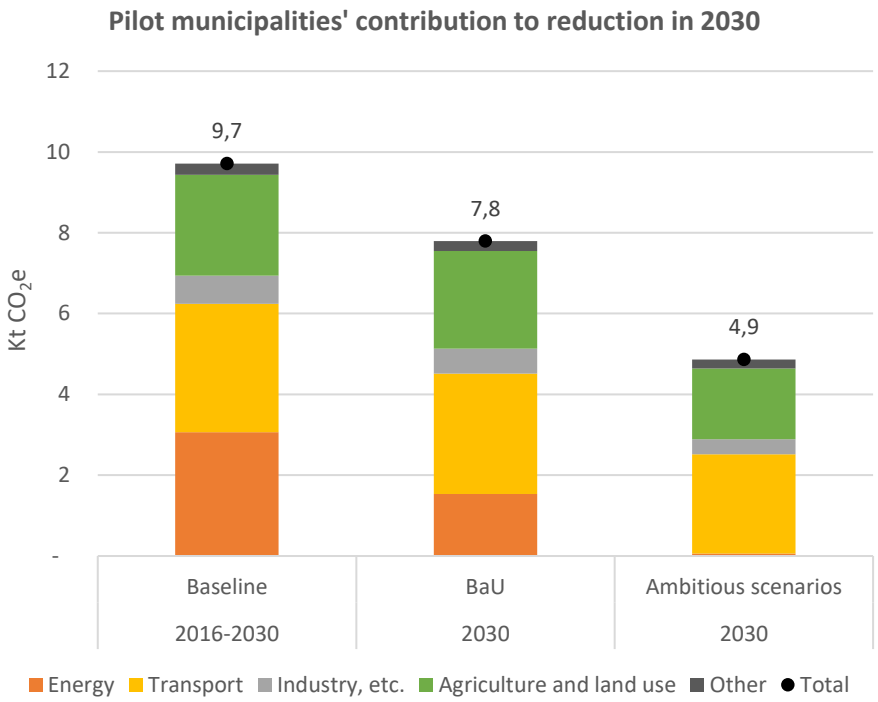

Figure 11: Total emissions by the 20 pilot municipalities in the baseline year, in the BaU scenario and in the ambitious scenario, respectively

In the BaU scenario, the pilot municipalities will realise reductions of 1,920 kt CO_2, corresponding to a reduction of 20%. In the ambitious scenario, the pilot municipalities will realise reductions of 4,850 kt CO_2, corresponding to a reduction of 50%.

CO_2 reductions by sector

Figure 13 shows the expected reductions for the 20 pilot municipalities in the ambitious scenario, broken down by sector.

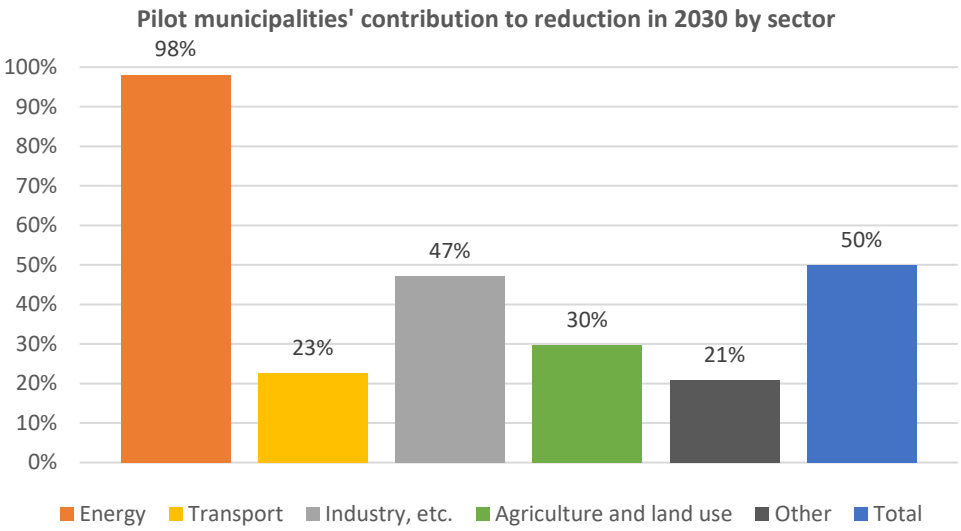

Figure 12: Sector reductions by pilot municipalities in the ambitious scenario in 2030, in % relative to the baseline year

It can be concluded from figure 13 above that the energy sector has the largest CO_2 reduction (98%). The reductions achieved in the remaining sectors are not as large, with reductions of between 21% and 47%.

11. Appendix 4: National pathway to realising the 70% target

The Danish Energy Agency has projected Denmark's national greenhouse gas emissions up to 2030 in Denmark's Climate Status and Outlook 2021 (CSO21). CSO21 shows a considerable reduction in greenhouse gas emissions from 2021 to 2030 of 8.23 million tonnes CO_2 equivalents following national reduction initiatives. However, there is still an emissions gap of 11.8 million tonnes CO_2 equivalents by 2030 relative to 1990, as illustrated in Figure 14.

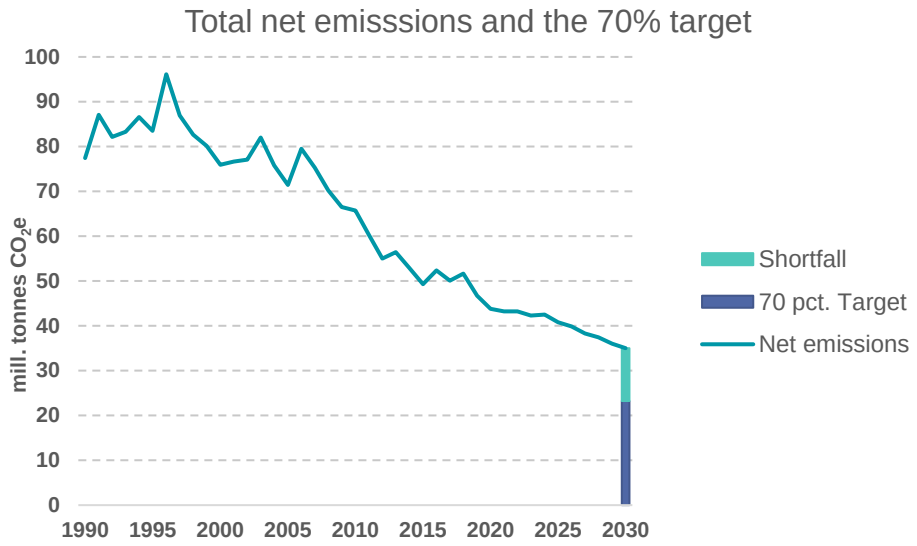

Figure 13: Denmark's projected greenhouse gas emissions up to 2030. Projections do not include the effect of the agreement on a green transition of the agricultural sector, the PtX strategy, and offshore wind turbines decided as part of the 2022 Finance Act

The government has set out four scenarios in its Climate Programme (Danish government, 2021), which explores different pathways to realising the 2030 target and closing the emissions gap of 11.8 million tonnes CO_2 equivalents.

The four scenarios cover these topics:

- Electrification
- Bioenergy
- Carbon capture and storage (CCS)
- Behavioural changes

The scenarios contain different assumptions regarding future biomass prices, future technology prices (within PtX[6], direct electrification and direct air capture, etc.), and future behavioural preferences. The scenarios therefore describe a range of outcomes for the green transition to long-term climate neutrality.

The electrification scenario primarily contains:

- Extensive conversion of oil-fired boilers and gas-fired boilers to heat pumps and district heating
- Broad deployment of offshore wind turbines in the North Sea
- Extensive degree of electrification of the transport sector
- Broad production of PtX fuels
- Broad use of pyrolysis
- Broad use of CCS[7] from waste-based CHP and biomass

The bioenergy scenario primarily contains:

- Broad consumption of bioenergy
- Broad biofuel blending in road transport
- Increased use of BECCS[8] and pyrolysis
- Broad use of feed additives and focus on slurry management

The carbon capture and storage (CCS) scenario primarily contains:

- Extensive use of CCS from waste-based CHP and biomass
- Extensive direct capture of CO_2 from the atmosphere
- Broad production of PtX fuels

The behavioural changes scenario primarily contains:

- Broad separation and recycling of plastic in particular
- Extensive transitioning with regard to feed additives, slurry additives and organically farmed land
- Broad use of pyrolysis and afforestation
- Broad conversion of oil-fired boilers and gas-fired boilers to heat pumps and district heating
- Broad degree of electrification of the transport sector

[6] PtX is short for power-to-X and is a term used to cover technologies to produce hydrogen, for example, through electrolysis. The hydrogen produced will be sustainable if produced from renewable electricity.
[7] CCS is short for carbon capture and storage, a technology that can be exploited at CHP plants, for example.
[8] BECCS is short for bioenergy with carbon capture and storage.

Furthermore, all scenarios include a broad degree of energy-efficiency improvements/change of fuels by refineries. There is also broad transitioning with regard to feed additives, slurry additives and organically farmed land in the three scenarios for electrification, bioenergy and CCS, respectively.

Total greenhouse gas emissions for the years 2018 and 2030 according to CSO21 and each climate action plan scenario are shown in figure 15. The figure shows the reduction effects of the additional initiatives in each scenario. All climate action plan scenarios achieve a net reduction in greenhouse gas emissions corresponding to the emissions gap of 11.8 million tonnes of CO_2 equivalents by 2030 through the respective additional initiatives. By 2050, biomass CCS (BECCS) and direct air capture and storage (DACS) will play a vital role in all scenarios in terms of meeting the target of net zero emissions. In particular, this is in order to offset greenhouse gas emissions from the agriculture sector.

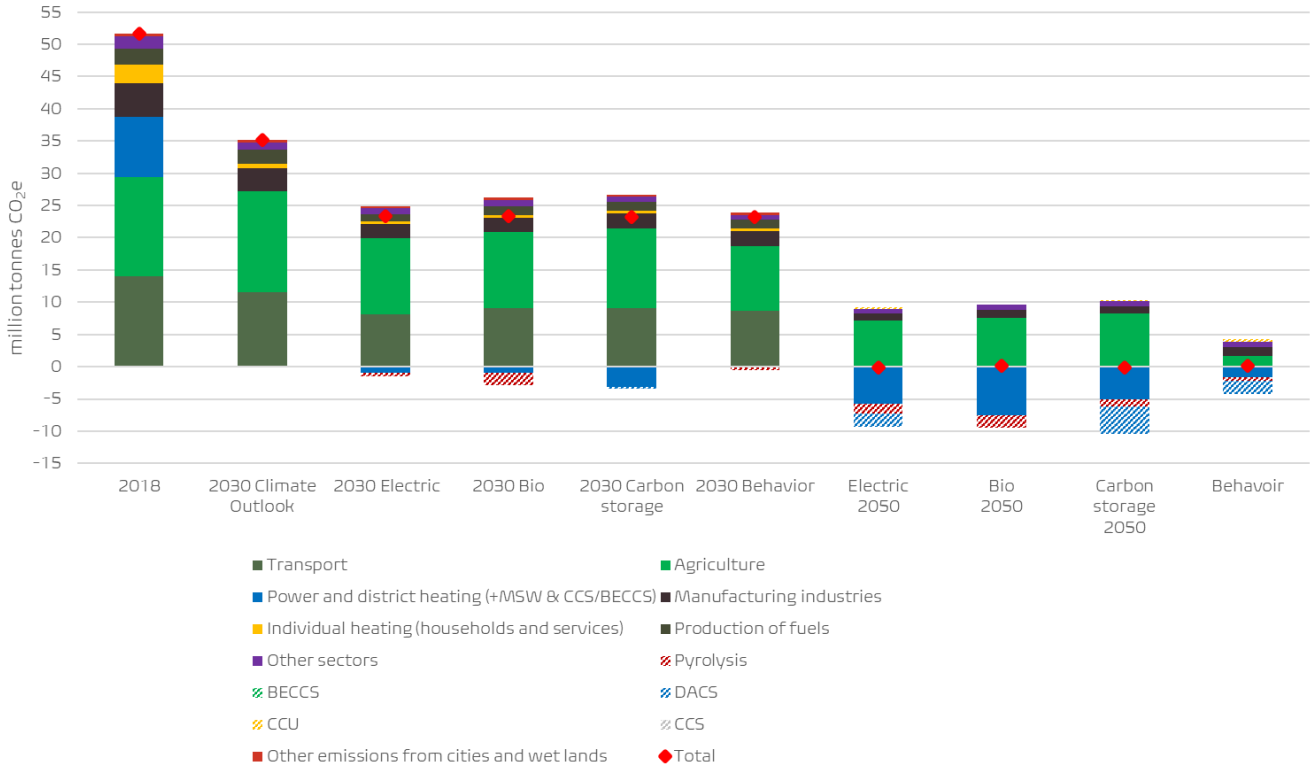

Figure 14: Total greenhouse gas emissions for the government's climate action plan scenarios in 2030 and 2050, compared with 2018 emissions and projected 2030 emissions in CSO21 (Danish government, 2021)

The greenhouse gas emission reductions in each scenario can be translated into relative reduction targets per sector for individual heating, electricity and district heating, transport, agriculture, manufacturing industries and 'Other', respectively. This is illustrated in figure 16.

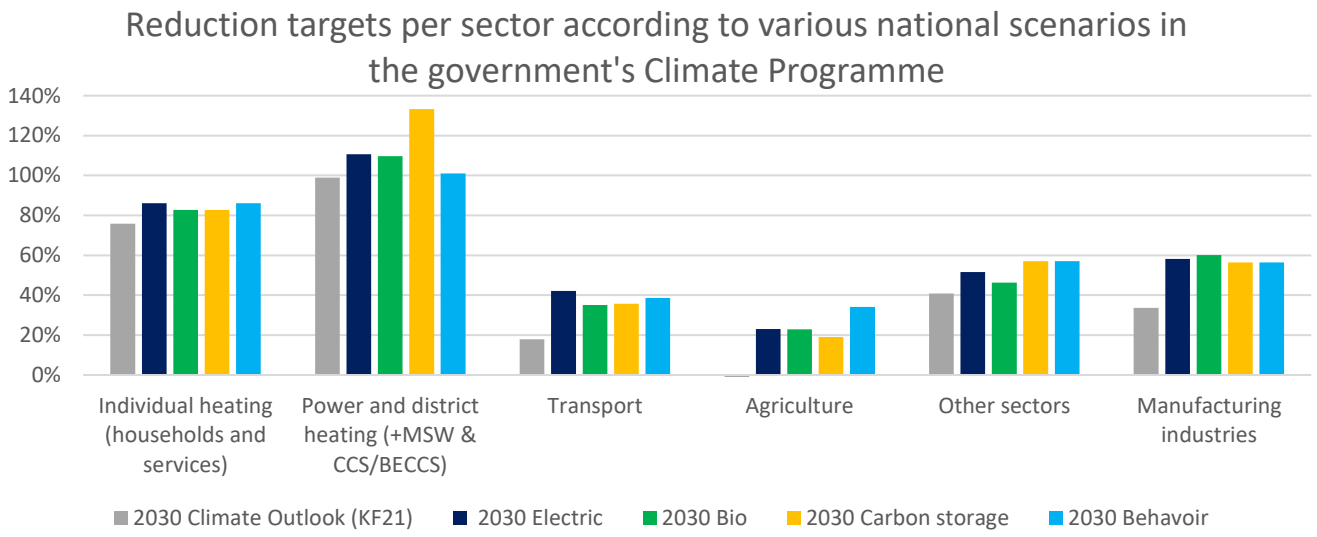

Figure 15: Reduction targets per sector according to various national scenarios in the government's Climate Programme (Danish government, 2021)

Figure 16 shows that the electricity and district heating sector will become net-negative with regard to greenhouse gas emissions in all scenarios. This means that CCS or BECCS is required to achieve greenhouse gas reductions above 100%.