Ea Energianalyse

Socio-economic optimum between energy efficiency, renewable energy, electrification and sector coupling

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Central findings

The Danish Government has determined that Denmark must reduce its CO2 emissions by 70 percent compared to 1990. The purpose of this analysis is to determine the socio-economic optimum between developments with renewable energy, energy efficiency and initiatives in electrification and sector coupling, thereby shedding more light on how Denmark can realise its objective as cheaply as possible.

The analysis is based primarily on data and results from the report 'Climate KPIs for the Confederation of Danish Industry (DI)', which paves the way with a 70 percent reduction of CO2 emissions in 2030, as well as an analysis for 'Synergy and Renovation on the Agenda' (original title: Synergi og Renovering på Dagsordenen), which calculates the socio-economic optimum between energy efficiency initiatives and supply measures.

Initiatives have been calculated for the following sectors: Construction, industrial, electric and district heating supply and transport as well as various cross-cutting measures, e.g. biofuels and electro-fuels.

In order to achieve a 70 percent objective, it has been assessed as necessary to deliver a reduction of approx. 17.5 million tonnes CO_2 compared to the baseline projection for 2019[1]. This also assumes a total reduction of approx. 4.9 Mt from initiatives in agriculture, LULUCF and environment so that the resulting shortfall requiring action from the energy and transport sector constitutes 12.7 million (see Figure 1).

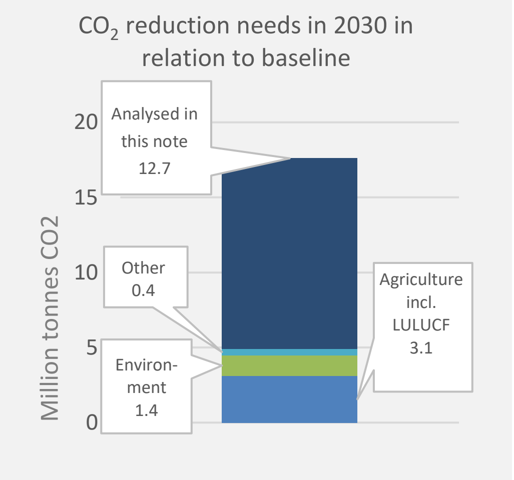

Figure 1: CO_2 reduction needs in 2030 in relation to baseline in order to achieve a 70% reduction objective.

At the request of the client, the analysed initiatives are broken down into three general categories: Energy Efficiency (EE), Electrification and Sector Coupling (E&SC) and Renewable Energy (RE). For example, heat pumps, electric vehicles and

[1] As the 2019 baseline projection had not been published at the time of the analysis, a baseline has been used based on the 2018 baseline projection corrected for initiatives that were adopted as part of the 2018 Danish Energy Agreement. According to the baseline projection the shortfall in 2030 constitutes 17.0 million tonnes of CO_2 while the baseline used in this study shows a shortfall of 17.5 Mt.

hydrogen power plants are placed under E&SC. The full CO_2 benefits of electrification and sector coupling can only be achieved if these plants are supplied with renewable energy. The analysis is thus based on the assumption that increased electricity use for E&SC is supplied (and priced) with renewable energy. The development of renewable energy is thus also included under E&SC.

Categorisation of mitigation measures

Energy efficiency

- Energy renovation of the existing building stock
- Energy optimisation of building installations and operations
- Energy savings in industry

Electrification and sector coupling

- Electric vehicles
- Increasing the spread of electric heat pumps
- Increased spread of district heating grid
- Production of electrofuels
- Developing renewable electricity capacity to cover the increased electrical consumption from electrification and sector coupling

Renewable energy

- Use of biodiesel and bioethanol for biogas as a replacement for diesel, petrol and natural gas
- Developing renewable power capacity in the electric and district heating sector, including ensuring that Denmark is not a net importer of electricity by 2030
- Diversion of plastic from waste incineration

Primary results:

- The initiatives identified in the analysis lead to a total reduction of CO_2 emissions of 9.6 million tonnes of CO_2 in 2030, corresponding to a reduction of 66 percent compared to 1990. The remaining CO_2 reductions needed to achieve the goal of 70 percent could be achieved, for example, by the additional production of electro-fuels, but this would presumably increase the total reduction costs considerably. It is expected that technological developments and innovation can lead to cheaper initiatives being developed to help achieve the final 4 percent reduction.
- The biggest contribution to the 70 percent goal comes from E&SC and the corresponding RE development. Implementation of E&SC reduces greenhouse gas emissions by 5.6 million tonnes of CO_2 in 2030,

corresponding to 44 percent of the necessary reduction in order to live up to the 70 percent goal. Heat pumps, both household and industrial,[2] contribute to a significant reduction of 2.2 million tonnes of CO_2, while initiatives to electrify the transport sector (excl. electro-fuels) provide a reduction of 1.5 million tonnes of CO_2.

- Other renewable energy initiatives (primarily the production and use of biogas and biofuels) give a reduction of 2 million tonnes of CO_2 in 2030, corresponding to 16 percent of the 70 percent goal.
- Implementation of existing energy efficiency technologies in buildings and industry also provides 2 million tonnes of CO_2 in 2030, or 16 percent of the 70 percent goal. Without investments in energy efficiency, the total additional costs[3] in the period leading up to 2030 will be around EUR 4 billion as opposed to around EUR 2.1 billion with energy efficiency measures (see Figure 2).
- Over the period 2020 to 2030, energy efficiency investments are thus estimated to entail socio-economic savings of around EUR 1.8 billion[4], if the alternative is increased developments with renewable energy. Investments in energy efficiency can thus almost halve net additional costs for the period leading up to 2030. The socio-economic savings of investing in energy efficiency consist of lower fuel and energy costs, including saving on the costs of expanding the electricity grid and developing electricity storage.
- The cheapest socio-economic solution for achieving a 66 percent reduction would result in necessary investments corresponding to EUR 23.4 billion[5] for electrification and sector coupling initiatives, energy efficiency and the production of renewable energy. Of this, EUR 3 billion[6] would be investments in energy efficiency. If investments are not made in energy efficiency, the total additional investments required to achieve a 66 percent reduction (solely through renewable energy and E&SC) increase to around EUR 27.7 billion[7].

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[2] Heat pumps are also expected to play an important part in the district heating supply in 2030, but the development of heat pumps in district heating supplies is already included in the presented baseline that calculates the effect of the 2018 Energy Agreement. This means that heat pumps in the district heating system are not included in CO_2 contributions in this analysis.
[3] Additional costs correspond to expenditure for investments minus savings in the form of fuel and investments in renewable energy.
[4] DKK 14 billion (currency exchange based on Morningstar data)
[5] DKK 175 billion.
[6] DKK 23 billion.
[7] DKK 207 billion.

- The costs of instruments is not included in the costing of energy efficiency, renewable energy and E&SC [8].

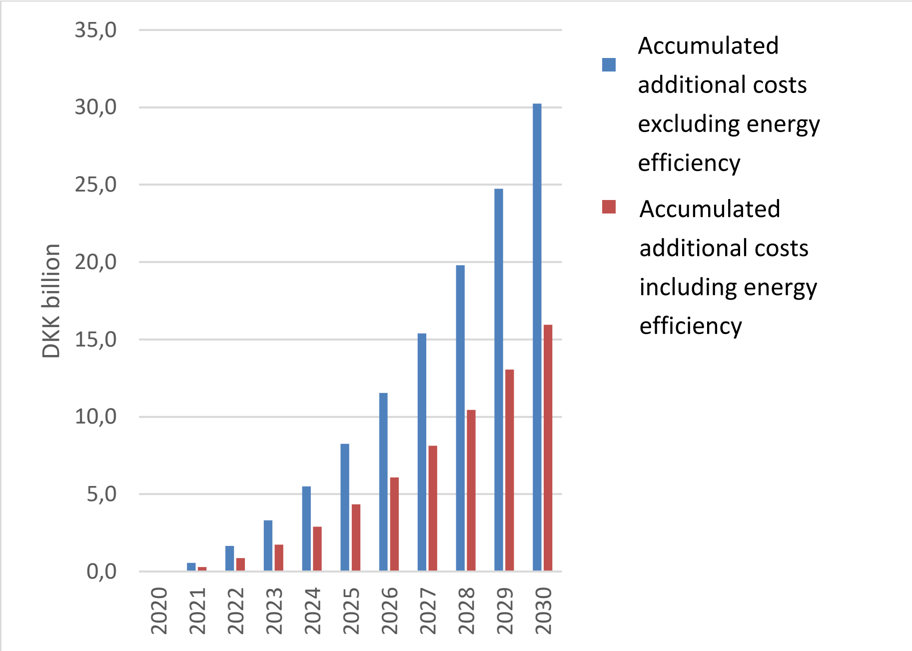


Figure 2: Accumulated additional costs for achieving a 66 percent reduction in greenhouse gases by 2030, including and excluding energy efficiency costs respectively. The costs do not include initiatives adopted by the 2018 Danish Energy Agreement; similarly, mitigation contributions from agriculture and the environment have not been valued. The reduction costs are calculated for 2030. The reduction plan and dosing procedure for initiatives between 2020 and 2030 has not been analysed; the indicated costs presume a linear development in the cost process between 2020 and 2030.

Selected key figures

Figure 3 summarises selected key figures from the analysis. All the initiatives presented and corresponding costs go beyond measures that are already in place, e.g. in the 2018 Danish Energy Agreement.

Column 1 shows that the total additional investments[9] in EUR billion comprises around EUR 23.4 billion[10], of which the largest share is in electrification and sector coupling. Investments are shown here as the absolute value of investment over the period 2020-30.

[8] Instrument costs could consist, for example, of costs for public information campaigns or deadweight loss in connection with support costs. The costs would depend on what regulation and type of instruments were used from a political standpoint.

[9] Additional investments correspond to new investments that are necessary in order to achieve a 66 percent reduction.

[10] DKK 175 billion

If investments are not made in energy efficiency, the total additional investments must be increased to EUR 27.7 billion[11] in order to achieve a 66 percent reduction. This covers the fact that energy efficiency initiatives themselves result in an investment of around EUR 3 billion[12], but save around 7.3 billion[13] in investments in the electrical grid, solar panels and wind power. The total investment needs are thus reduced by around EUR 4.2 billion[14].

Column 2 shows the savings[15] on fuel and imported electricity. The biggest share of the savings is in this category. Both electrification and sector coupling technologies and energy efficiency measures result in considerable savings. There is a slight increase in fuel costs in RE because bioethanol and biofuel are more expensive than diesel and petrol. The savings in the period 2020 to 2030 correspond to EUR 21.2 billion[16].

Column 3 shows the annual net costs[17], which total around EUR 388 million[18] in 2030, of which EE measures contribute with a net saving. Without investments in energy efficiency, the total additional costs[19] in the period leading up to 2030 will be around EUR 4 billion[20] as opposed to around EUR 2.1 billion[21] with energy efficiency measures. Over the period 2020 to 2030, energy efficiency investments are thus estimated to entail socio-economic savings of around EUR 1.8 billion[22], if the alternative is increased developments with renewable energy. This corresponds to almost half of the total additional costs[23].

Net costs include the costs of fuel/electricity, annuity from investments (capital costs), changes in operations and maintenance and multiple benefits, for example

[11] DKK 207 billion
[12] DKK 23 billion
[13] DKK 55 billion
[14] DKK 32 billion
[15] Savings concerns lower costs for the purchasing of electricity and fuel as a result of investments in new technology.
[16] DKK 159 billion
[17] Net costs express the total cost connected to the initiatives and is the sum of the changes in capital costs (related to investments) and changes in operating costs and fuel savings.
[18] DKK 2.9 billion
19 Additional costs correspond to expenditure for investments minus the savings of investing in energy efficiency in the form of lower fuel and energy costs, including saved expenditure that would otherwise be spent on expanding the electricity grid and developing electricity storage.

[20] DKK 30 billion
[21] DKK 16 billion
[22] DKK 14 billion
[23] The reduction plan and dosing procedure for initiatives between 2020 and 2030 has not been analysed. The estimated savings of DKK 14 billion between 2020 and 2030 presumes a linear increase in savings, from DKK 0 in 2020 to DKK 2.6 billion in 2030.

the effects on health. It is assumed that the investments could be paid off over the technology's lifetime with a real interest rate of 4 percent.

If it was decided not to implement the EE initiatives, it would not only be annual savings of EUR 267.6 million[24] that would be lost, but the costs in the other sectors would also increase by a combined EUR/year 80.2 million[25], if the alternative is the

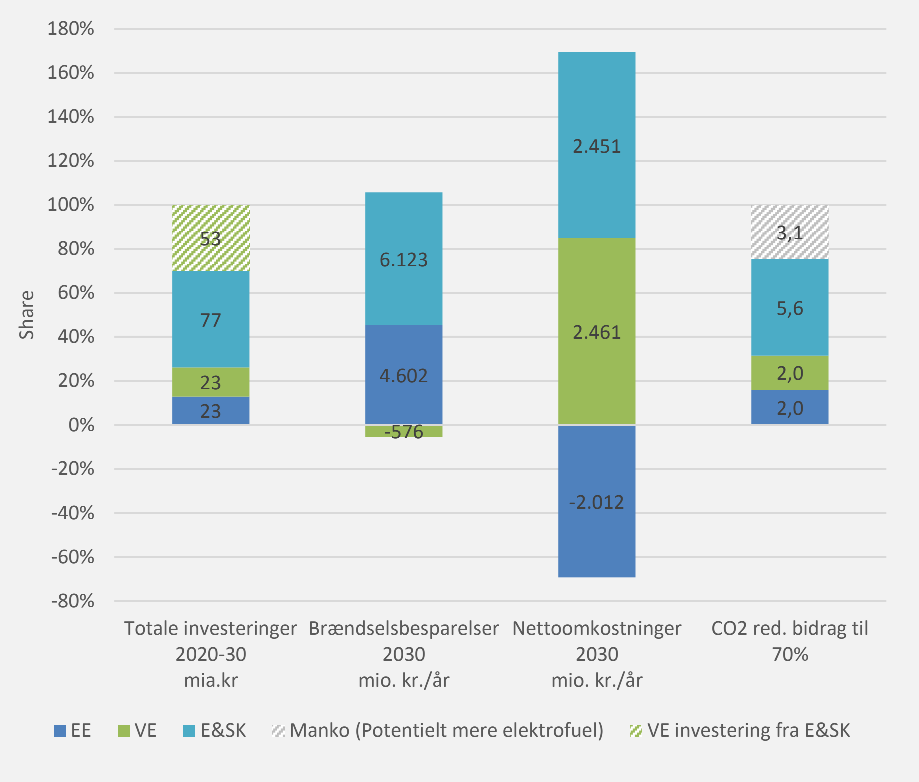


Figure 3: This shows the amount per category for investments, fuel savings and net costs, as well as how much these contribute towards the CO_2 reductions. The absolute values are also shown.

development of renewable energy.

Column 4 shows the extent to which each of the categories contributes towards the 70 percent goal (million tonnes of CO_2 reduction). The biggest contribution comes from the sector coupling initiatives. The identified measures achieve a total reduction of around 66 percent compared to 1990. The last reductions could be achieved using electrofuels.

[24] DKK 2 billion

[25] DKK/year 0.6 billion

Total investments 2020-30 DKK billion	Fuel savings 2030 million DKK/year	Net costs 2030 million DDK/year	CO2 rev. contribution to 70%

Introduction and purpose

The Danish Government has decided that Denmark must reduce its climate gas emissions by 70 percent compared to 1990 figures. By all accounts, this is a highly ambitious goal and requires effort from all fronts. The government in 2019 presented is a proposal for a binding climate agreement and then to initiate negotiations on a final action plan.

Since summer 2019, Ea Energy Analyses has drafted two reports on the economics of the green transition: one is an analysis for the Confederation of Danish Industry (DI), which paves the way towards a 70% reduction of climate gases by 2030. The other is a cross-sectional analysis for 'Synergy and Renovation on the Agenda' (original title: Synergi og Renovering på Dagsordenen), which calculates the socio-economic optimum between energy efficiency initiatives and supply measures.

The purpose of this analysis, which is based on the aforementioned reports, is to shed light on the socio-economic optimum between developments with renewable energy, energy efficiency and initiatives in electrification and sector coupling. In comparison with the analysis for DI, a more comprehensive analysis of energy efficiency initiatives has been conducted here[26]. The basis for the analysis is that Denmark must realise the goal of a 70 percent reduction in greenhouse gas emissions by 2030 as cheaply as possible.

Method:

The analysis focuses on initiatives in construction, industry, electric and district heating supply and transport as well as a number of cross-cutting measures, e.g. biofuels and electro-fuels. In establishing the initiatives, a long-term perspective towards a fossil-free energy system in 2050 has been taken into account, i.e. that the measures do not halt or hinder the long-term transition, but pave the way towards a fossil-free energy system. The initiatives do not constitute an exhaustive list of potential measures, but in our opinion comprise the lion's share of relevant initiatives.

The initiatives are compared with a baseline without the initiatives. The baseline is based on the Danish Energy Agency's baseline projection from 2018, but includes estimates of significance from Denmark's 2018 Energy Agreement:

- Three wind farms
- A pool for technology-neutral tenders
- Reduction of electric heating tariffs
- Energy saving efforts
- Revised estimate for biogas production

[26] The Analysis for Synergy and Renovation on the Agenda calculated the total socio-economic potential for energy savings in 2030 and 2050 respectively without any special focus on the 70% goal and without taking the initiatives decided in the 2018 Energy Agreement into account. The analysis for the Confederation of Danish Industry (DI) identified measures for achieving a 66 percent reduction in 2030, although there were certain EE initiatives (electricity savings and certain heating savings) that were not analysed in great detail.

It also includes minor changes due to the calculations being conducted using EA's models and tools for the Danish energy sector. This ensures that the initiatives and baseline are compared according to the same conditions.

The calculations focus on initiatives in energy-related greenhouse gas emissions.

As the reduction goal covers the total greenhouse gas emissions in Denmark, estimates for the development and potential of greenhouse gas emissions in agriculture, industrial gases and other emissions have also been added.

Reduction needs

The figure below shows how the emissions in the 2018 baseline projection are broken down into four sectors.

Due to the Energy Agreement, adopted after the 2018 baseline projection, emissions in 2030 are expected to be 38.8 million tonnes of CO_2/year rather than 51 million tonnes of CO_2/year. This constitutes the baseline for the analyses. The figure also shows the values for 2030 with a 60 percent and 70 percent reduction compared to 1990.

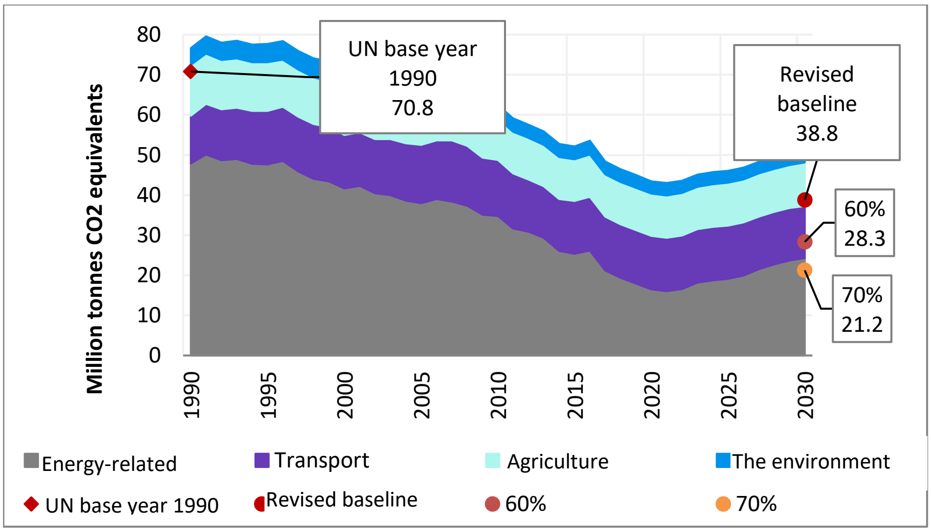


Figure 3: Emissions in the 2018 baseline projections. Revised baselines and reduction goals are shown as dots.

The table below shows the reduction needs depending on the specific reduction goal. The first column shows what the emissions need to be reduced to by 2030 in order to achieve the goal. The second column shows how much the emissions need to be reduced by in 2030 compared to the baseline to achieve the goal. It is evident from this that a reduction of 17.5 million tonnes is needed to achieve the government's goal of a 70 percent reduction in relation to 1990.

Million tonnes	Maximum emissions 2030	Reduction needs in relation to baseline Mt CO_2	Reduction needs in relation to agriculture/environment
60% red.	28.3	10.4	5.5
65% red.	24.8	14.0	9.1
70% red.	21.2	**17.5**	**12.7**

Table 1: Reduction needs dependent on goals.

Part of these reductions is expected to be provided by agriculture and environment. In this context, environment deals with the treatment of wastewater and industrial gases. An economic calculation has not been made for these sectors, but it has been assessed how large a reduction they can be expected to provide. Table 2 summarises the contributions.

Million tonnes	*Mitigation contributions 2030*
Agriculture	*1.3*
Agriculture LULUCF	*1.8*
The environment	*1.4*
Other	*0.4*
Total	***4.9***

Table 2: Mitigation contributions from sectors not treated in detail in the

Agriculture constitutes a relatively large share of the total greenhouse gas emissions in Denmark in 2030. It is assumed that measures concerning the management of crops, fertiliser, domestic animals and land use will contribute with a reduction of around 1.3 million tonnes of CO_2, corresponding to a reduction of around 10 percent compared to 1990's agricultural figures. This assessment is based on reports from the agricultural sector.

In addition, agriculture releases greenhouse gas emissions as a result of changes in soil carbon balance (LULUCF). Here, a total reduction potential of 1.8 million tonnes of CO_2 is estimated. Emissions from LULUCF are not included in the 1990 emission figures that have been used as the basis for the 70 percent reduction goal.

In environment, a mitigation contribution of 50 percent in relation to 2020 is assumed, corresponding to 63 percent in relation to 1990.

The category 'Other' covers emissions quantified by DCE in addition to those emissions directly related to Danish energy consumption, in particularly cross-border corrections for diesel and volatile and indirect emissions. A total contribution of 0.4 million tonnes of CO_2 is estimated, corresponding to 35 percent in relation to 2020.

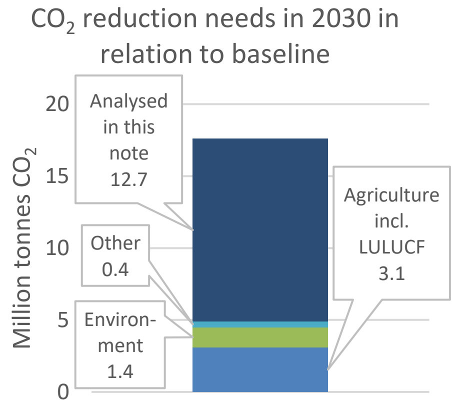


Figure 4: CO_2 reduction needs in 2030 in relation to baseline

After taking mitigation contributions from agriculture, environment and indirect emissions into account, the remaining initiatives need to deliver a **CO_2 reduction of 12.7 million tonnes** in order to achieve the 70 percent goal, as shown in Figure 5.

The revised baseline shows a substantial net import of electricity to Denmark in 2030. This import is attributed to a CO_2 emission of 200 g/kWh based on model calculations. Emissions connected to imports are included in the Danish figures. It should be highlighted that it has not yet been clarified which methodical accounting principle will be used to handle the import/export of electricity in connection with fulfilment of the 70 percent goal.

Reduction measures

Initiatives in construction, industry, electric and district heating supplies and transport are broken down into three general categories: Energy Efficiency (EE), Electrification and Sector Coupling (E&SC) and Renewable Energy (RE).

The individual measures and a detailed description of the methodology can be found in the report 'Climate KPIs for the Confederation of Danish Industry (DI) (EA Energy Analyses, 2019), which can be downloaded from Ea's website. As the analysed CO_2 reduction initiatives result in a reduction of 66 percent on their own, in general all the analysed initiatives are included in the analysis. Individual energy efficiency measures have been left out however, as their margin reduction costs are higher than RE-based supply.

Energy efficiency (EE)

Covers technologies that optimise energy transformation or technologies that optimise energy consumption via thermal insulation, dosing (valves) or intelligent building systems, to name some examples. Energy efficiency also affects sector coupling and the renewable energy categories – for example, the efficiency of a heat pump can be increased when combined with a low temperature district heating grid (4th generation district heating) or by using excess heat.

Electrification and sector coupling (E&SC)

Concerns technology, which optimises the interaction between energy production and energy consumption by exploiting the conversion potential and the flexibility that can be created across the energy system. This category includes the energy transformative technologies, for example heat pumps, modern cooling systems, power to gas and electric vehicles, as well as energy storage and the resulting shift in energy consumption (including intelligent building systems). Sector coupling contributes towards an exploitation of the flexibility found primarily in thermal systems and gas supplies to optimise the potential of fluctuating electricity production based on renewable sources.

The full CO_2 benefits of electrification and sector coupling can only be achieved if sector coupling technologies such as heat pumps, electric vehicles and electrolysis plants are supplied with renewable energy. The analysis is thus based on the assumption that increased electricity for electrification and sector coupling is supplied (and priced) with renewable energy. Calculation-wise, the RE electricity consumption and its costs are considered as part of the electrification and sector coupling measures; we have opted however to itemise the cost in a number of the subsequent figures

Renewable energy (RE)

Energy production based on renewable energy, covers electricity production via solar panels, wind turbines and biomass, district heating production via biomass, biogas and solar heating and the production of biofuels such as biodiesel, bioethanol and biogas. Electric heat pumps, electric vehicles and electrofuels are handled as E&SC initiatives.

Table 3 summarises how the various initiatives are classified.

Biogas, biofuel and electro-fuels are cross-cutting measures, which can have influence across the sectors.

Electro-fuels are a scalable initiative that can in principle replace the use of fossil fuels in all sectors. Electro-fuels are assumed to be produced from hydrogen generated by electrolysis plants, which use electricity from renewable energy sources.

Biogas and biofuel are assessed as being scalable to a more limited extent, as the production requires biological material.

Buildings	
Building envelope	*EE*
Management/heating installations	*EE (E&SC)*
Switch to individual heat pumps	*E&SC*
Conversion to district heating	*E&SC*
Industry	
Efficiency	*EE*
Heat pumps/electric boilers	*E&SC*
Biomass/biofuel	*RE*
Electric and district heating supply	
RE in electricity supply	*RE*
Heat pumps in district heating supply	*E&SC*
Biomass, solar power in district heating supply	*RE*
Transport	
Electric cars	*E&SC*
Electric light commercial vehicles	*E&SC*
Electric heavy goods vehicles	*E&SC*
Electric buses	*E&SC*
Biogas for heavy goods vehicles, light commercial vehicles and buses	*RE*
Electric ferries + shore power	*E&SC*
Cross-cutting initiatives	
Biogas	*RE*
Biofuel	*RE*
Electrofuels	*E&SC*

Analysis results

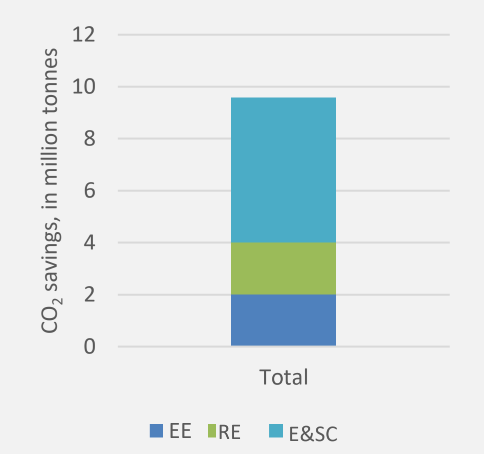


Figure 6: Resulting reduction of CO_2 emissions from the initiatives in 2030.

Reduction of emissions

Figure 6 summarises the CO_2 reductions divided into the three categories: E&SC, RE and EE. It is assumed that electro-fuels contribute with a reduction of 1 million tonnes of CO_2. The cost of electro-fuels is estimated at DKK 1,850 per tonne of CO_2.

In total a reduction of 9.6 million tonnes is achieved in relation to the baseline, which roughly corresponds to a 66 percent reduction compared to 1990. In order to achieve the 70 percent goal, the emissions must be further reduced by 3.1 million tonnes. The 70 percent goal could be achieved by increasing the share of electro-fuels, for example. This is not shown in the figure, as electro-fuels are among the most expensive initiatives and it is possible that by 2030 there will be other, cheaper reduction possibilities.

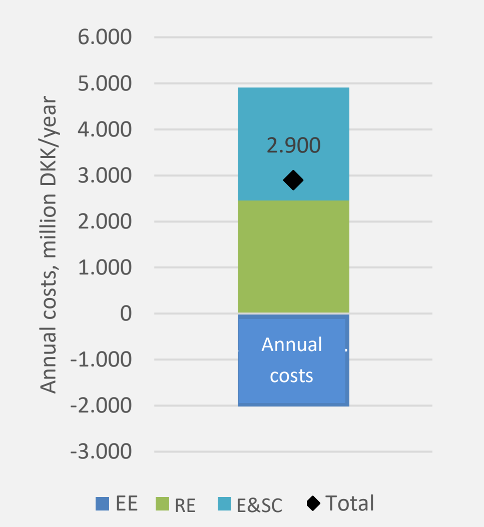


Figure 7: The annual additional costs in 2030 of achieving a reduction of 10.7 million tonnes of CO_2.

Total additional costs, 2030

The total additional costs of achieving the reductions of 9.6 million tonnes of CO_2 are around EUR 388 million[27] annually in 2030, as shown in Figure 7.

The energy efficiency initiatives result in a total saving of around EUR 267.6 million, while E&SC initiatives bring an additional cost of EUR 334.5 million and the RE initiatives EUR 334.5 million.

[27] DKK 2.9 billion

The calculations are based on electro-fuels contributing with a reduction of 1 million tonnes of CO_2.

If electro-fuel production is increased so that the 70 percent goal can be achieved, the annual costs are expected to increase by around EUR/year 776.1 million[28].

If the EE measures are not implemented but the same CO_2 reduction of 66 percent is still to be achieved, the total additional cost increases from EUR/year 388 million[29] to EUR/year 735.9 million[30] in 2030. The EE initiatives thus constitute savings of EUR 347.9[31]. Assuming there is a linear increase in savings from 2020 to 2030, the total savings over the period would be EUR 1.8 billion[32].

It should be noted that this does not include instrument costs, as these would depend on what regulation and type of instruments were used from a political standpoint. Instrument costs could consist, for example, of costs for public information campaigns or deadweight loss in connection with support costs.

Figure 8 shows the annual costs broken down into different costing categories.

- **Capital costs:** Annual cost of investments. Includes financing.
- **Operation and maintenance (O&M):** Running costs for operating and maintaining the infrastructure and investments, e.g. heating installations or vehicles
- **Fuel costs:** Costs for fuel and imported electricity. For fuel consumption that requires investment in underlying Danish production (e.g. installation of new wind power) a share of the fuel costs have been moved to the capital and O&M costs.
- **Multiple benefits**: Benefits derived from energy-saving projects in the form of improved comfort and productivity, for example, as well as learning and better health.

Figure 8 shows net costs. For example, when an electric car replaces a car that runs on fossil fuels, only the additional costs of the electric car are included. It is clear that the transition results in significantly higher capital costs in all categories, but also lower costs overall for the import of fuel and electricity.

[28] DKK/year 5.8 billion
[29] DKK/year 2.9 billion
[30] DKK/year 5.5 billion
[31] DKK 2.6 billion
[32] DKK 14 billion

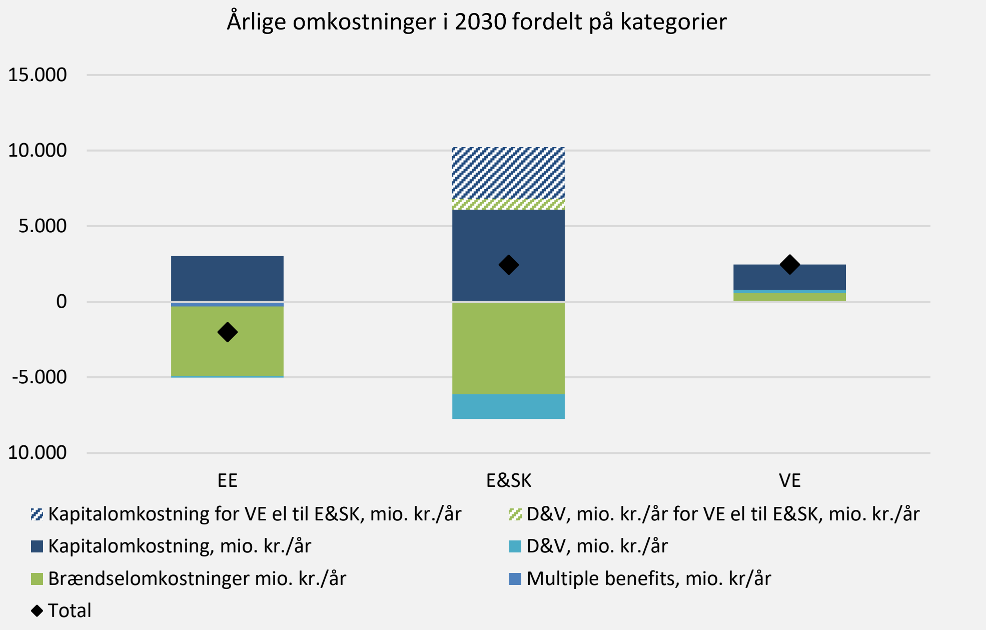


Figure 8: The annual additional costs in 2030 of achieving a reduction of 9.6 million tonnes of CO_2 broken down into different costing types

Initiatives such as the phasing-in of electric cars and electric heat pumps and the production of electro-fuels requires an increased development of an RE-based electricity supply. These costs are shown as hatched areas in Figure 8, because they are categorised under electrification and sector coupling, but also cover investments in RE production capacity.

Annual costs in 2030 broken down into categories

Bioethanol and biodiesel are considered as being imported to Denmark and thus dealt with as fuels in the calculations.

Multiple benefits appear in connection with energy improvements (EE) and constitute a saving for society of around EUR 40.1 million[33] annually in 2030.

Capital costs for RE electricity for E&SC, million DKK/year

O&M, million DKK/year for RE electricity for E&SC, million DKK/year

Capital costs, million DKK/year

O&M million DKK/year

Fuel costs million DKK/year

Multiple benefits, million DKK/year

[33] DKK 300 million

Total investments in the period 2020-2030

Figure 9 shows the total necessary investments over the period 2020-2030.

As previously mentioned, an increase in electric vehicles, heat pumps and electro-fuels will lead to investments in the RE electricity capacity. These investments are shown separately, as they are attached to both E&SC and RE (hatched area).

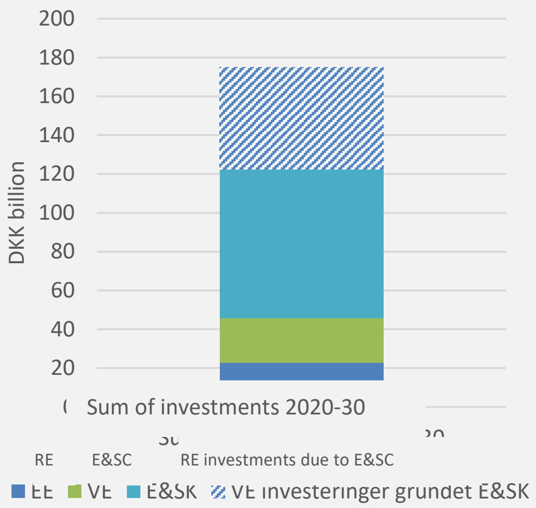


Figure 9: The total investments in the period 2020-30

Appendix

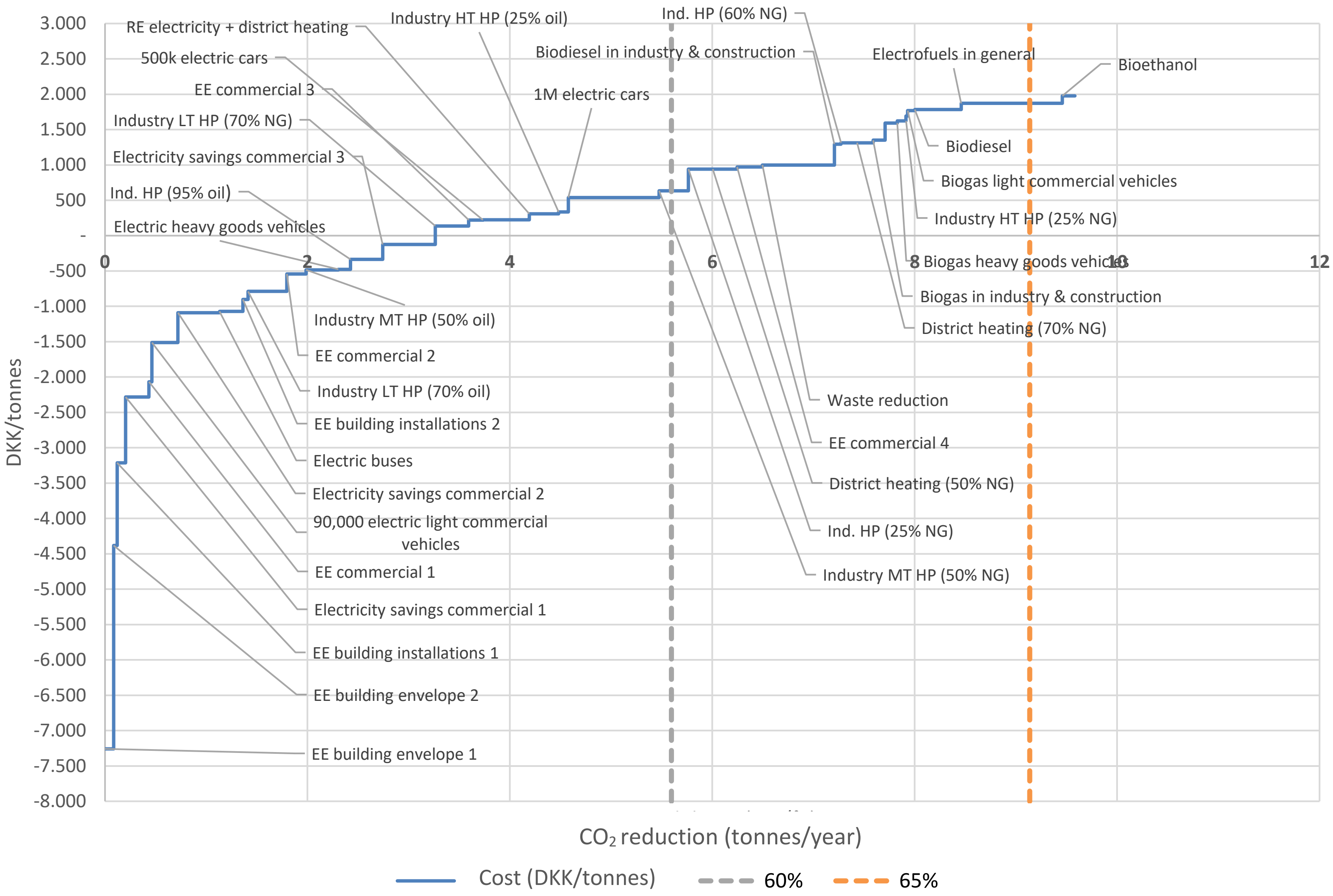
List of CO2 reduction measures and their contribution in million tonnes of CO2.

	EE	RE	SC
1M electric cars			0.897
500k electric cars			0.458
90,000 electric light commercial vehicles			0.257
Waste reduction		0.710	
Biodiesel		0.457	
Biodiesel in industry & construction		0.066	
Bioethanol		0.124	
Biogas in industry & construction		0.117	
Biogas heavy goods vehicles		0.121	
Biogas coaches		0.016	
Biogas light commercial vehicles		0.071	
EE building installations 1	0.085		
EE building installations 2	0.051		
EE commercial 1	0.030		
EE commercial 2	0.190		
EE commercial 3	0.140		
EE commercial 4	0.250		
EE building envelope 1	0.085		
EE building envelope 2	0.034		
Electricity savings commercial 1	0.230		
Electricity savings commercial 2	0.410		
Electricity savings commercial 3	0.520		
Electric buses			0.231
Electrofuels in general			1.000
Electric heavy goods vehicles			0.121
District heating (50% NG)			0.241
District heating (70% NG)			0.159
Ind. HP (25% NG)			0.241
Ind. HP (60% NG)			0.159
Ind. HP (95% oil)			0.317
Industry HT HP (25% NG)			0.087
Industry HT HP (25% oil)			0.096
Industry LT HP (70% NG)			0.330
Industry LT HP (70% oil)			0.384
Industry MT HP (50% NG)			0.290
Industry MT HP (50% oil)			0.318
RE electricity + district heating		0.290	
Grand total	**2.025**	**1.973**	**5.585**

List of CO2 reduction measures and corresponding CO2 reduction costs in DKK/tonnes

	EE	RE	SC
1M electric cars			539
500k electric cars			223
90,000 electric light commercial vehicles			-1512
Waste reduction		1000	
Biodiesel		1783	
Biodiesel in industry & construction		1295	
Bioethanol		1977	
Biogas in industry & construction		1349	
Biogas heavy goods vehicles		1593	
Biogas coaches		1693	
Biogas light commercial vehicles		1768	
EE building installations 1	-3212		
EE building installations 2	-902		
EE commercial 1	-2067		
EE commercial 2	-542		
EE commercial 3	221		
EE commercial 4	972		
EE building envelope 1	-7259		
EE building envelope 2	-4382		
Electricity savings commercial 1	-2283		
Electricity savings commercial 2	-1090		
Electricity savings commercial 3	-125		
Electric buses			-1072
Electrofuels in general			1870
Electric heavy goods vehicles			-476
District heating (50% NG)			941
District heating (70% NG)			1314
Ind. HP (25% NG)			941
Ind. HP (60% NG)			1314
Ind. HP (95% oil)			-336
Industry HT HP (25% NG)			1623
Industry HT HP (25% oil)			336
Industry LT HP (70% NG)			137
Industry LT HP (70% oil)			-789
Industry MT HP (50% NG)			634
Industry MT HP (50% oil)			-484
RE electricity + district heating		309	

MAC curve



RE electricity + district heating
500k electric cars
EE commercial 3
Industry LT HP (70% NG)
Electricity savings commercial 3
Ind. HP (95% oil)
Electric heavy goods vehicles
Industry HT HP (25% oil)
Ind. HP (60% NG)
Biodiesel in industry & construction
1M electric cars
Electrofuels in general
Bioethanol
Biodiesel
Biogas light commercial vehicles
Industry HT HP (25% NG)
Biogas heavy goods vehicles
Biogas in industry & construction
District heating (70% NG)
Industry MT HP (50% oil)
EE commercial 2
Industry LT HP (70% oil)
EE building installations 2
Electric buses
Electricity savings commercial 2
90,000 electric light commercial vehicles
EE commercial 1
Electricity savings commercial 1
EE building installations 1
EE building envelope 2
EE building envelope 1
Waste reduction
EE commercial 4
District heating (50% NG)
Ind. HP (25% NG)
Industry MT HP (50% NG)
DKK/tonnes
CO_2 reduction (tonnes/year)
Cost (DKK/tonnes)
60%
65%

Note about MAC curve:

The numbering of the different energy efficiency measures covers different cost groups of initiatives and cannot therefore be directly coupled to any specific initiatives.

Note concerning the replacement of natural gas boilers: there are two levels of initiatives in place, whereby the first initiative is based on a natural replacement process. This corresponds to a ban on installing new natural gas boilers and results in a reduction of approx. 50% in 2030 compared to 2020. All natural gas boilers that have reached the end of their service life are replaced with an air-to-water heat pump or district heating, where it is assumed that district heating is on a par economically with individual air-to-water heat pumps. Natural gas is often located in or close to district heating areas. A 50% reduction measure is thus broken down, whereby 25% are replaced with air-to-water heat pumps and 25% replaced with district heating (the initiatives 'Ind. HP (25% NG)' and 'District heating (50% NG)'). The second initiative is based on a faster transition, where a total reduction of 70% is achieved by 2030. This initiative is an extension of previous measures and thus describes the consequences of increasing the goal in 2030 from 50% to 70% (the initiatives 'Ind. HP (60% NG)' and 'District heating (70% NG)'). A 70% reduction requires replacing a share of the natural gas boilers before they have reached the end of their service life, which raises the costs of replacement, as the investments for these installations have not necessarily depreciated yet. Again, the boilers are placed with both air-to-water heat pumps and district heating.