Expert Group for a
green tax reform

Documentation and sensitivity calculations of effects for industry and heating

EKSPERTGRUPPEN FOR EN
GRØN SKATTEREFORM

Contents

0. Overall method

This note documents the calculation methods used in the Expert Group's first interim report. The calculations are based on the same analytical approach used in the inter-ministerial *Afgifts- og tilskudsanalysen på energiområdet* (The tax and subsidy analysis in the energy sector) completed in 2017. A partial analysis model has been set up, in which sector-specific demand curves for CO_2 are determined, and which includes the main effects concerning CO_2, sector burden, revenue and socio-economics. The results are consistent with general equilibrium modelling and (implicitly) include general equilibrium effects in the form of changes in prices, wages and sector adjustments[1].

Inter-ministerial work is underway to finalise the general equilibrium model GreenREFORM, which will be used in the Expert Group's final report to the extent possible. The model is expected to be applicable to the areas covered by the first interim report as well as new areas such as non-energy emissions from agriculture. In addition, the model will be able to directly take into account general equilibrium effects, including interaction effects between restructuring of taxes for different sectors.

The Expert Group's first interim report calculates the effects of restructuring of taxes on CO_2 emissions based on data and assumptions about:

1. The basis for the CO_2 emissions
2. The functional form of demand for energy/CO_2
3. Price sensitivity of demand (elasticity)

The identification of these is discussed below. There is a high degree of uncertainty associated with the estimated effects, as there is a high degree of uncertainty about the functional form and elasticities, as well as a high degree of uncertainty about the bases and their projection, especially when allocated to the different tax categories. With the 70 per cent target, the quantitative target is known. With the very high uncertainty about the base and effects of introducing taxes and subsidies, as discussed in this report, it is very uncertain to determine a tax rate/subsidy pool that will lead to a specific CO_2 reduction. This also makes it very uncertain to quantify the socio-economic cost of achieving a given target. A number of sensitivity analyses have therefore been carried out on the tax model.

Models with a subsidy pool are included in the first interim report, which is assumed to target CCS/BECCS. In addition, there are outlined models in which a base deduction is given in the tax. Modelling of the CCS/BECCS subsidy pool and the base deduction is also described below. Both parts are modelled in connection with taxes and are consistent accordingly.

[1] For example, shifting from CO_2-intensive industries to less CO_2-intensive industries is taken into account through a higher tax burden on the CO_2-intensive industries. The tax burden is expected to largely spill over into lower wages and will displace labour from CO_2-intensive occupations towards less CO_2-intensive occupations.

1. Calculation principles for industry

1.1. Basis for industry

To calculate the impact of a given CO_2 tax, it is necessary to know the consumption of each type of energy and the CO_2 emissions by sectors.

The calculations for the first interim report use a sectoral breakdown reflecting different tax bases and whether the tax base is emissions allowance covered or not. The CO_2 base for industry includes emissions from their production processes, while the emissions from heating, incl. industrial heating, and road transport are excluded. The projection of energy consumption and CO_2 emissions is subject to considerable uncertainty, as is the distribution of energy consumption by tax base.

The CO_2 base is by default based on the energy balance from Climate Status and Outlook 2021. However, a correction will be made as the Ministry of Finance's latest projection of the emissions allowance price expects a much higher emissions allowance price going forward than the emissions allowance price used for the Climate Status and Outlook 2021. The higher emissions allowance price must be expected to reduce the CO_2 emissions of industry covered by emissions allowances compared to the estimate in Climate Status and Outlook 2021.

With Climate Status and Outlook 2021, a projection was concretely based on a emissions allowance price of approximately DKK 300 and DKK 350 in 2025 and 2030 respectively. The latest projection estimates a emissions allowance price of around DKK 650 and DKK 750 in 2025 and 2030, respectively, i.e. around DKK 350 and DKK 400/tonne more (2022 prices). In the first interim report of the Expert Group, the isolated effect of the higher emissions allowance price in 2025 and 2030 is estimated, using the same approach as for calculating the effects of restructuring of taxes, *see Section 1.4*.

With the corrected base, the CO_2 emissions for industry in total will be approximately 7.33 million tonnes in 2030, corresponding to a downward adjustment compared to Climate Status and Outlook 2021 of 1.18 million tonnes of CO_2, *see Table 1*. Emissions from mineralogical processes, etc., account for about 31 per cent of the total CO_2 base in 2030 and are thus by far the largest sector in terms of CO_2 emissions. The sector is characterised by relatively high emissions from the production process, which are not directly linked to energy consumption. Emissions between energy and non-energy are roughly equal. Cement production is associated with the largest emissions in the sector, accounting for about 70 per cent of the sector's emissions.

The other sectors with large emissions are mainly the North Sea and refineries.

Table 1
Base in 2025 and 2030

	Climate Status and Outlook 2021				**Applied base – updated on the basis of new emissions allowance price projection**			
	Base in 2025	Share of base in 2025	Base in 2030	Share of base in 2030	Base in 2025	Share of base in 2025	Base in 2030	Share of base in 2030
	Million tonnes CO_2	Percentage	Million tonnes CO_2	Percentage	Million tonnes CO_2	Percentage	Million tonnes CO_2	Percentage
General process (ETS)[1]	0.70	7	0.66	8	0.60	7	0.49	7
General process (non-ETS)[1]	0.70	7	0.66	8	0.70	8	0.66	9
Agriculture etc. excluding agricultural diesel	0.22	2	0.16	2	0.22	2	0.16	2
Agricultural diesel	0.57	6	0.54	6	0.57	6	0.54	7
Horticulture (ETS)	0.04	0	0.03	0	0.03	0	0.02	0
Horticulture (non-ETS)	0.07	1	0.05	1	0.07	1	0.05	1
Mineralogical processes, etc. (energy - cement)	1.00	10	0.97	11	0.85	10	0.73	10
Mineralogical processes, etc. (energy - non-cement)	0.52	5	0.54	6	0.48	5	0.47	6
Mineralogical processes, etc. (non-energy - cement)	1.11	12	1.05	12	0.95	11	0.78	11
Mineralogical processes etc. (non-energy - non-cement)	0.32	3	0.33	4	0.30	3	0.28	4
North Sea	1.06	11	1.16	14	0.96	11	0.99	14
Refineries[2]	0.98	10	0.98	12	0.88	10	0.81	11
Fisheries	0.25	3	0.25	3	0.25	3	0.25	3
Ferries	0.61	6	0.60	7	0.61	7	0.60	8
Railway	0.18	2	0.06	1	0.18	2	0.06	1
Fossils for electricity production[3]	1.14	12	0.31	4	1.10	12	0.28	4
Domestic flights	0.16	2	0.17	2	0.15	2	0.16	2
Total	9.63	100	8.51	100	8.90	100	7.33	100

Note: The base is calculated as CO_2 emissions and emissions of other greenhouse gases linked to the burning of fossil fuels as well as non-energy-related emissions from mineralogical processes. Emissions of greenhouse gases other than CO_2 are very limited. In addition, there are minor emissions of greenhouse gases other than CO_2 associated with the burning of biogenic fuels, which are not included in the base. In 2030, they are estimated to amount to about 0.1 million tonne of CO_2e by the Climate Status and Outlook 2021. There is uncertainty linked to the distribution of greenhouse gases other than CO_2 on fossil fuels or biogenic fuels. A limited amount of district heating is used for the process, which is not included. All piped gas is counted as fossil, as the marginal consumption of piped gas affects the fossil piped gas consumption, as the amount of biogas in the natural gas network is assumed to be a fixed amount. 1) The base for the general process is, before correction for the higher emissions allowance price, equally distributed between the ETS and non-ETS sectors, because it is estimated to be approximately equally distributed. 2) Refineries use some refinery gas to produce electricity and district heating, which is included in the base for refineries. 3) For fossil fuels for electricity production, the total base for collective heat and electricity including waste is allocated to heat and electricity respectively on the basis of current rules on the allocation of the tax base for heat in CHP plants. The split between electricity and heat will depend on the specific model.
Source: Denmark's Climate Status and Outlook 2021 and own calculations

Table 2 shows the energy consumption of industries for their production processes, broken down by fuel, in 2030. The energy consumption is based on Climate Status and Outlook 2021 and has not been corrected for the effect of the higher emissions allowance price.

Table 2
Energy consumption by fuel composition for industry in 2030

PJ	Coal	Oil	Gas[3]	Waste[3]	Biomass	Biofuels	Electricity	District heating	Surplus heating and ambient heat	Total
General process	0.1	1.6	22.1	0.7	2.8	0.2	5.4	1.2	3.7	37.9
Agriculture and horticulture, excluding agricultural diesel	0.2	2.1	1.8	0.0	2.1	0.4	6.4	1.6	2.3	16.5
Agricultural diesel	0.0	7.2	0.0	0.0	0.0	0.4	0.0	0.0	0.0	7.7
Mineralogical processes, etc.	9.3	0.5	7.0	5.0	0.2	0.0	0.2	0.0	0.0	22.2
North Sea[1]	0.0	0.0	20.3	0.0	0.0	0.0	0.0	0.0	0.0	20.3
Refineries[1]	0.0	0.2	16.9	0.0	0.0	0.0	0.0	0.0	0.0	17.1
Fisheries	0.0	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3
Ferries	0.0	6.7	1.5	0.0	0.0	0.0	0.0	0.0	0.0	8.2
Railway	0.0	0.8	0.0	0.0	0.0	0.1	3.2	0.0	0.0	4.2
Fossils for electricity production[2]	0.0	0.2	6.6	8.3	17.8	0.0	0.0	0.0	0.0	33.0
Domestic flights	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3

Note: 1) Energy consumption for the North Sea and refineries is calculated, including flaring, which amounts to 2.1 PJ and 0.3 PJ gas, respectively. 2) For fossil fuels for electricity production, the total base for collective heat and electricity, including flaring, is 0.3 PJ. waste is allocated to heat and electricity, respectively, based on the current rules on allocating the tax base for heat to CHP plants. The split between electricity and heat will depend on the specific model. 3) Gas and waste include both fossil and biogenic fuels. The energy consumption in the table above differs from the energy balance available on the Danish Energy Agency's website. For mineralogical processes, etc., the deviation is due, among other things, to the inclusion of heat in the energy balance. For fisheries, the difference is due to the inclusion in the energy balance of diesel for recreational vessels, which is not included in the above. The difference in energy consumption for domestic flights and ferries is due to the inclusion of maritime and air transport to Greenland and the Faroe Islands.
Source: Denmark's Climate Status and Outlook 2021 and own calculations

1.2. Shape of the demand curve

This section discusses the methodological considerations behind the assumptions on the shape of the demand curve for CO_2 emissions.

An increase in the CO_2 tax raises the price of a given fossil energy product, such as oil or natural gas. Thereby, the consumption of the energy product and the CO_2 emissions decrease. The consumption of a given energy product, and hence the demand curve, depends on three terms, each of which depends on the price of the energy product and the relative price ratio with other energy products and production factors.

For example, consumption of oil is determined as:

(1) Consumption of oil = (Production of goods for which energy is used) x (energy consumption/production of goods for which energy is used) x (oil consumption/energy consumption).

Consumption of energy products in a pure form very rarely provides direct utility. However, energy is used together with other factors of production to produce goods and services that provide utility or as an input to production of the goods and services themselves. In this way, energy is not a service but a factor of production.

The first term, which is an expression of the consumption of a given good or service, points in the direction of a demand curve where the consumption of energy, here oil, never becomes zero (See e.g. Nordhaus, William D. "Do Real-Output and Real-Wage Measures Capture Reality? The History of Lighting Suggests not" NBER (1996)), since consumption of a good rarely ceases completely, even at very high prices.

For many of the goods or services produced using energy, the cost of energy is a small part of the price. However, there are also goods and services that are very energy-intensive. The effect via the first term is thus very varying. If the price elasticity of a given good is -1 and energy costs in isolation contribute 2 per cent of the total price, the contribution to the elasticity from the first term is -0.02. If, on the other hand, the energy costs make up 20 per cent, the contribution to the elasticity from the first term is -0.2 etc.

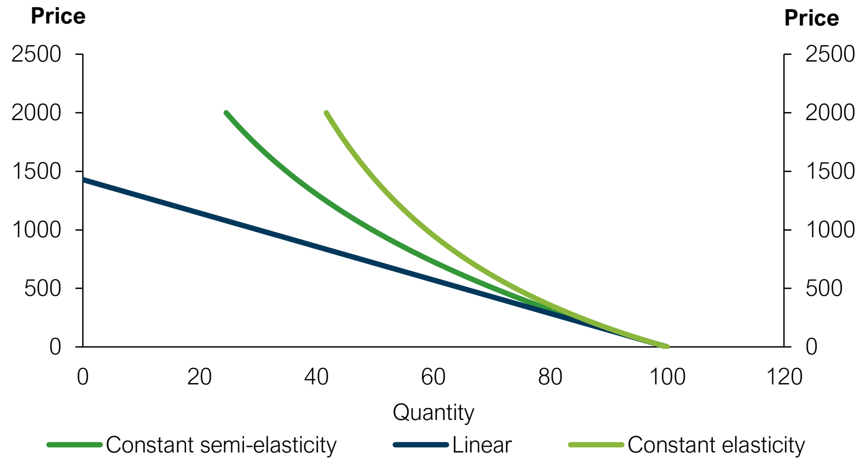
The second term, which is an expression of the energy intensity of a given good or service (typically substitution between energy and labour or substitution between energy and capital), also points in the direction of a demand curve where the consumption of energy, here oil, does not become zero, since the use of energy for a given product or service will typically be difficult to replace with other factors of production fully. These substitution elasticities are very difficult to estimate on aggregate data, as energy intensity varies much more than, for example, capital intensity and labour intensity in manufacturing industries, where it is true that some forms of capital are substitutes for energy, while others are complements.

The third part, which is an expression of the specific energy product's share of the total energy consumption (the "share curve"), points in the direction of a curve that, at a final price, brings the consumption of the given energy product to an end. For example, fossil oil could be replaced by biofuels. The shape of the "share curve" will depend on the price ratio between the type of energy used and its substitutes. For example, the “share curve” may have a steep slope at a high price (where, other things being equal, many have already switched to the alternative, but for the latter, a lot more is needed) and a similar slope at a low price (where, other things being equal, the alternatives are not very competitive), while the slope will be small in the price range where the price of the fossil and the alternatives are, for many, about the same.

The shape of the actual energy demand curve is not really known. Instead of the demand curve having constant price elasticity (isoelastic) or being linear, it is considered a more realistic starting point that the actual overall shape of the demand curve lies somewhere between these two curves. Thus, both the demand curve with constant price elasticity and the linear demand curve are judged to have properties that are not reliable or reasonable in case of major changes in prices. For the demand curve with constant price elasticity, the value of energy consumption as a share of total consumption could be very high if the constant elasticity is low and the price becomes very high. Conversely, the linear demand curve can lead to a very rapid phase-out of energy consumption and thus CO_2 emissions. Therefore, a demand curve with constant semi-elasticity is used, *see Figure 1*.

The impact of restructuring of taxes will often be estimated within a small price range, by which large restructuring of taxes typically are outside the basis of experience. Furthermore, for smaller changes, the choice of functional form is of minor importance, but for larger changes, the functional form of the demand curve has a significant impact on the calculated effects. This contributes to uncertainty in assessing the rate needed to achieve a given CO_2 reduction.

Figure 1. Three types of demand curves



Source: Own calculations.

The demand curve with constant semi-elasticity can be written as:

(1) $Q = e^{-Z\,x\,P+b}$

Where Z is the semi-elasticity, P is the price, Q is the quantity, and b is a constant term.
For a given quantity, Q_0, the quantity Q can be found by changing the price from P_0 to P:

(2) $Q = Q_0\,x\,e^{-Z\cdot(P-P_0)}$

The demand curve used in the first interim report gives the volume (Q) and the change in volume (ΔQ) in million tonnes of CO_2 and the price (P) and change (ΔP) in DKK/tonne of CO_2. The demand curve is thus not defined in energy units but in CO_2 units.

By differentiating equation (2) with respect to P, the following expression can be obtained:

(3) $Z = -\left(\frac{\Delta Q}{Q}\right)/\Delta P$

A demand curve with constant semi-elasticity (Z) is thus characterised by the fact that a change in price by one unit (ΔP) leads to the same percentage change in volume $(\frac{\Delta Q}{Q})$. The semi-elasticity (Z) thus expresses the percentage change in CO_2 emissions for a fixed change in price per tonne of CO_2. However, for calculation purposes, the semi-elasticities are first calculated in energy units and then converted to CO_2 via an emission factor, *see Section 1.3*.

Equation (3) can be rewritten as:

(4) $\Delta Q = -Z \, x \, Q \, x \, \Delta P$

At a given point (Q, P) on the curve, the slope of the tangent line corresponds to $-Z \, x \, Q$. The term $Q \, x \, \Delta P$ indicates the immediate revenue effect in DKK million for a given amount of CO_2 in million tonnes (Q) and a given tax change in DKK/tonne of CO_2 (ΔP). The semi-elasticity (Z) can thus be converted at a given point (Q, P) into a number of million tonnes of CO_2 per DKK 100 million of revenue.

The price elasticity as conventionally defined, i.e. percentage change in quantity over percentage change in price, can be found by rewriting equation (4):

(5) $\varepsilon \equiv \frac{\Delta Q/Q}{\Delta P/P} = -P \, x \, Z$

The price elasticity (ε) of the curve is thus not constant but is proportional to the price and the semi-elasticity (which is constant). That is, the price elasticity (ε) increases with increasing price along the demand curve with constant semi-elasticity. This is because with the demand curve with constant semi-elasticity, the base is reduced by the same percentage change per unit change in price, see above. But one unit change in price represents a smaller and smaller percentage increase in price. That is, the numerator $(\frac{\Delta Q}{Q})$ in equation (5) is the same per unit change in price, while the denominator $(\frac{\Delta P}{P})$ gets smaller and smaller.

In the following, "price elasticities" refer to conventionally defined price elasticities, see equation (5).

1.3. Price sensitivity of demand

The price sensitivity of demand (the slope of the demand curve) is determined by semi-elasticity (Z). This is divided into the parameters:

- The technical effect (Z_t)
- Impact on the industry structure (Z_s)

Hence, formula (1), see *Section 1.2*, can be written as:

(6) $Q = e^{-(Z_t + Z_s) \, x \, P + b}$,

where $Z_t + Z_s = Z$.

The technical effect (Z_t) is the transition of production via energy efficiency improvements and the transition from the use of fossil fuels to renewable energy or electricity, e.g. via investment in heat pumps and in some cases also switching between fossil fuels. The effect on the industry structure (Z_s) consists partly of cross-border trade effects and partly of shifts in production from CO_2-intensive companies to non-CO_2-intensive ones, including via relocation of production.

Table 3 shows the semi-elasticities used for the different sectors, divided into the technical semi-elasticity and the structural semi-elasticity, respectively. The semi-elasticity varies considerably across sectors, including the distribution of technical and industry structural effects.

Table 3
Semi-elasticities for CO_2 tax, which also include process emissions from mineralogical processes, etc.

	Semi-elasticity ($Z = Z_t + Z_s$)	of which technical semi-elasticity (Z_t)	of which structural semi-elasticity (Z_s)
	- - Percentage change in CO_2 by a change in price with DKK 1/tonne - -		
General process (ETS)	**0.10**	0.07	0.03
General process (non-ETS)	**0.10**	0.07	0.03
Agriculture etc. excluding agricultural diesel	**0.10**	0.07	0.03
Agricultural diesel	**0.02**	0.02	-
Horticulture (ETS)	**0.10**	0.07	0.03
Horticulture (non-ETS)	**0.10**	0.07	0.03
Mineralogical processes, etc. (cement)	**0.59**	0.07	0.52
Mineralogical processes, etc. (non-cement)	**0.13**	0.04	0.09
North Sea	**0.05**	0.04	0.01
Refineries	**0.15**	0.05	0.10
Fisheries	**0.09**	0.03	0.06
Ferries	**0.05**	0.03	0.02
Railway	**0.02**	0.02	-
Fossils for electricity production[1]	**0.05**	0.02	0.02
Domestic flights	**0.03**	0.01	0.01

Note: Semi-elasticities are shown as positive numbers, but reflect a decrease in CO_2 emissions with an increase in price. The total semi-elasticity does not necessarily sum to the sum of technical and structural semi-elasticity due to rounding. The calculations use semi-elasticities with several decimals. 1) Computational elasticity, *see Table 5 and note to Table 4*.
Source: Own calculations.

The overall semi-elasticity is highest for mineralogical processes, etc. (cement), where the CO_2 base is reduced by about 0.59 per cent for every DKK/tonne of CO_2 the tax is increased. Of this, about 0.52 percentage points are attributed to structural effects, i.e. the vast majority, and about 0.07 percentage points to technical effects. The reduction of about 0.59 per cent per DKK 1/tonne tax increase reflects at a given point on the demand curve, (Q,P), a decrease in the CO_2 emission of about 0.59 million tonnes per DKK 100 million of immediate revenue.

The overall semi-elasticity is lowest for agricultural diesel and railway, where the CO_2 base for each of the two sectors is reduced by about 0.02 per cent when the CO_2 tax is increased by DKK 1/tonne of CO_2. For both sectors, the entire reduction is attributed to technical effects.

The semi-elasticities are determined based on Climate Status and Outlook 2021, including the underlying prices, i.e. before correction for the higher emissions allowance price. In the following sections, the determination of the semi-elasticities is further explained.

1.3.1. Interaction between technical effect and structural effect

The technical elasticity and the elasticity regarding structural adjustment are by default calculated as isolated/marginal effects. At the margin, CO_2 reductions can be decomposed into technical effect and structural effect:

(7) $Q = \frac{Q}{Y} \cdot Y$

(8) $\Rightarrow \frac{\Delta Q}{Q} = \frac{\Delta Y}{Y} + \frac{\Delta\left(\frac{Q}{Y}\right)}{\frac{Q}{Y}}$

Equation (7) states that CO_2 emissions(Q) can be calculated as production (Y) multiplied by the CO_2 content of a unit produced (Q/Y).

Equation (7) can be rewritten as equation (8), which states that CO_2 reductions are a sum of the structural effect ($\Delta Y/Y$), i.e. reduction in production for a given CO_2 content per unit produced, and the technical effect ($\Delta\frac{Q}{Y}/\frac{Q}{Y}$), i.e. reduction in CO_2 content in a unit produced for a given production. This relationship applies regardless of the functional form of the demand curve.

For very small tax shocks, the two effects could be combined, as the behavioural effects would be limited and so would the overlap between the technical effect and the structural effect. Moreover, for marginal tax increases, the burden after behavioural response is broadly equal to the immediate burden. Partly through the limited behavioural effects, partly through the switching costs associated with changing behaviour (e.g. investing in energy efficiency improvements or heat pumps) – i.e. the gain from changing behaviour is less than the tax savings achieved.

In the case of major tax shocks, there will initially be an overlap. Companies will be able to avoid a share of the immediate cost increase via technological transition (electrification, energy efficiency improvement, etc.), which creates an interaction between the technical and structural effects (technical transition possibilities, reduces structural effects). Conversely, it can also be said that structural effects reduce the impact of technical transition (when reducing production, the energy consumption from the reduced consumption cannot also be converted).

The demand curve with the constant semi-elastic form takes this interaction/overlap into account in the way that the base (CO_2 emissions) is gradually reduced due to marginal changes in the price (e.g. via marginal tax increase). With each marginal increase in the price, the base is reduced as a result of partly the technical effect and partly the structural effect. Along the demand curve with constant semi-elasticity, the relationship between technical semi-elasticity and industry structural semi-elasticity is maintained.

There is no "correct" method to quantify the isolated impact of the contribution of the technical effect and the structural effect of major changes. It will depend on the order (again it cannot be determined whether to convert to heat pump first and then reduce production, or to reduce production first and then convert the remaining energy consumption to heat pump). The technical semi-elasticity as a share of the total semi-elasticity was used to calculate the technical effect as a share of the total CO_2 effect in the first interim report of the Expert Group.

1.3.2. Technical effect

The technical effect is divided into two main components:

a. *Energy efficiency*
b. *Switching from fossil fuels to renewable energy or electricity and switching between fossil fuels*

The assessment of technical effects is based, among others, on the study Labandeira et al. (2017)[2], which is a meta-analysis of price elasticities associated with energy consumption. The meta-analysis is based on about 400 research articles, some looking at total energy consumption and others at a subset, such as oil consumption. The choice of the meta-analysis in question should be seen in the light of the fact that other meta-analyses focus primarily on the transport sector, whereas Labandeira et al. (2017) incorporate other energy types such as electricity and natural gas. Labandeira et al. (2017) find an overall price elasticity of total energy consumption with respect to energy prices of about -0.2 in the short run and about -0.6 in the long run.

This price elasticity captures in principle all reduction options (both technical and structural), but it is estimated that for e.g. oil the vast majority of fuel price variation in international studies follows international fluctuations in fuel price (rather than national tax shocks). Since international price changes can be passed on to consumers to a greater extent than domestic tax shocks, this implies, other things being equal, that previous studies mainly capture technical switching of production rather than changes in the size of different sectors.

In determining the technical semi-elasticities, it is assumed that the weighted effect of energy taxes regarding technical effects should roughly correspond to the long-term price elasticity from Labandeira et al. (2017) of about -0.6, calculated at expected prices in 2030 excl. tax and emissions allowance, see also later. However, as there are very large uncertainties about this long-run price elasticity for total energy consumption, as well as large uncertainties associated with harmonising price elasticities for the different tax bases with this total price elasticity, it does not take as a basis that the weighted price elasticity should correspond exactly to -0.6. The determination of the technical semi-elasticities has thus also been made on the basis of assessments of technical transitions' opportunities and potentials in the different sectors.

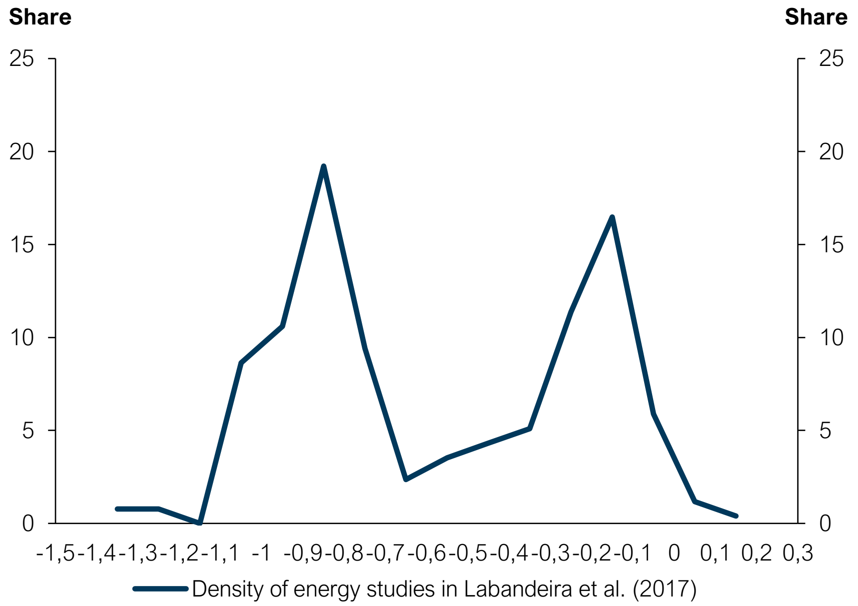
It is assumed that the long-term elasticity holds in 2030, but there is uncertainty as to when the "short" and "long" terms are, *see Section 1.6*.

The estimated elasticities in the underlying studies, which underlie the elasticity of about -0.6 from Labandeira et al. (2017), are distributed with two "humps". The first hump has a local maximum at about -0.2, and the second hump has a local maximum at about -0.9, *see Figure 2*. The two humps are estimated to be primarily explained by different estimation methods. Thus, the studies behind the elasticities around -0.2 are largely based on time series analysis, while the studies concentrated around -0.9 are largely based on cross-sectional analysis. The weighted average is about -0.6. Thus, information from all the studies underlying the meta-analysis

[2] Labandeira, Xavier, José M. Labeaga, and Xiral López-Otero. "A meta-analysis on the price elasticity of energy demand." Energy policy 102 (2017): 549-568.

is used by taking the mean when the applied overall weighted price elasticity is held against the long-run price elasticity from Labandeira et al. (2017).

Figure 2. Distribution of elasticities in the meta-analysis Labandeira et al. (2017)



Source: Data behind the meta-analysis requested from Labandeira, Xavier and own calculations.

The elasticity of about -0.6 reflects total energy consumption. For individual sectors, this elasticity may be deviated from when sector-specific conditions suggest it. For example, there will typically be fewer substitution opportunities towards renewable energy for transport, so this area will have a lower elasticity. Where there is evidence to deviate from the general elasticity in a minor part of the economy, there will be other areas for which elasticities will need to be adjusted to reach the overall effect.

Furthermore, when looking at fossil fuel elasticities within different sectors, there may be cross-price elasticities between other energy forms that would not be included in an elasticity for total energy consumption. Denmark also uses much more renewable energy than other countries, partly due to the high level of taxation, while fossil fuel prices in other countries have typically not been high enough for substitution towards renewable energy. In isolation, this argues for higher Danish elasticities on fossil fuels.

The concrete sector-specific technical semi-elasticities used in the Expert Group's first interim report can be seen in *Table 4* (same as in *Table 3*). The semi-elasticities are divided between contribution from energy efficiency improvement, transition to electricity or biomass, and transition to other fossil fuels with lower CO_2 content. This distribution is subject to considerable uncertainty. The semi-elasticities given in *Table 4* apply to a CO_2 tax that includes process emissions from mineralogical processes, etc.

Table 4
Semi-elasticities for technical effects of CO_2 tax, which also include process emissions from mineralogical processes, etc., and price elasticity for prices including tax and emissions allowance

	Total technical price elasticity (for price incl. tax and emissions allowance)	Technical semi-elasticity	of this, efficiency improvement	of this, transition to electricity	of this, transition to biomass	of this, transition to other fossil fuels
		- *Percentage change in CO_2 by a change in the price by 1 DKK/tonne* - -				
General process (ETS)	1.1	**0.07**	0.02	0.02	0.02	-
General process (non-ETS)	1.1	**0.07**	0.02	0.02	0.02	-
Agriculture, etc. excl. agricultural diesel	1.1	**0.07**	0.02	0.02	0.02	-
Agricultural diesel	0.3	**0.02**	0.02	-	-	-
Horticulture (ETS)	1.1	**0.07**	0.02	0.02	0.02	-
Horticulture (non-ETS)	1.1	**0.07**	0.02	0.02	0.02	-
Mineralogical processes, etc. (cement)[1]	0.3	**0.07**	0.04	-	0.02	0.01
Mineralogical processes, etc. (non-cement)[1]	0.3	**0.04**	0.02	-	0.02	-
North Sea	0.4	**0.04**	0.02	0.02	-	-
Refineries	0.5	**0.05**	0.03	-	0.02	-
Fisheries	0.4	**0.03**	0.03	-	-	-
Ferries	0.4	**0.03**	0.01	0.01	-	+0.00
Railway	0.3	**0.02**	0.01	0.01	-	-
Fossils for electricity production[2]	0.6	**0.02**				
Domestic flights	0.2	**0.01**	0.01	-	-	-
Total	**0.6**	0.05				

Note: Elasticities and semi-elasticities are shown as positive numbers, but reflect a decrease in CO_2 emissions with an increase in price. The total technical semi-elasticity may not sum to the sum of the individual partial semi-elasticities due to rounding. Semi-elasticities with several decimal places are used in the calculations. The prices used as the basis for the calculation of the price elasticities are based on Climate Status and Outlook 2021, as is the emissions allowance price, and are calculated in 2021 prices. It is based on current taxes including the increase of DKK 6/GJ agreed with the Green Tax Reform. General process, agriculture (excluding agricultural diesel) and horticulture are considered together, and an average price for these sectors has been used for the conversion of semi-elasticity to price elasticity. 1) In the case of tax on both fuel-related emissions and process emissions from mineralogical processes etc. If only a tax is imposed on e.g. fuel-related emissions, the semi-elasticities will be different. The point elasticity is calculated on the basis of a price which is a weighted average of the price of the process emissions (the emissions allowance price) and the price of the fuel-related emissions. 2) Fossil fuels for electricity production are based on an overall conventional price elasticity of -1 (i.e. technical effects and structural effects, which are assumed to be equally distributed) for an energy tax, which is converted to a semi-elasticity in energy units at an assumed price of DKK 85/GJ (the electricity producers' selling price), based on Climate Status and Outlook 2021. Thus, a semi-elasticity of -1.18 calculated in energy units (1/85 x 100) has been used, which in turn has been converted to a total semi-elasticity of approximately 0.05 calculated in CO_2 emission units. When converting from energy units to CO_2 units, a higher CO_2 content in the reduced energy consumption for electricity production is assumed for a CO_2 tax than for an energy tax. This may explain why the point elasticity of technical effect, as shown in *Table 4*, of -0.6 is higher than -0.5 (the point elasticity of technical effect for energy tax). The elasticity for fossil fuels for electricity production is a computational elasticity, which likewise is computationally equally distributed between technical effect and structural effect. The actual impact will depend, among other things, on the effects on waste, where the instruments have not yet been finalised, *see Section 4*. The computational effect used could potentially differ significantly from an effect based on a detailed analysis.
Source: Own calculations.

The technical semi-elasticity is highest for cement, general process and agriculture (excluding agricultural diesel) and horticulture, followed by refineries. This means that the largest CO_2 reduction per kroner paid in tax is expected here via technical transition. Conversely, technical transition is expected to take place to a lesser extent for agricultural diesel, domestic flights and railway, among others. Generally, the overall technical elasticity is higher in sectors where energy is used to produce heat than in areas where engines are used. The higher elasticities in the area of heating are partly due to the fact that there is considered to be a better opportunity for transition to electricity and biomass and partly to the fact that there may be a better opportunity for efficiency improvements, for example, through the use of internal surplus heating.

In terms of calculation, the semi-elasticities are first calculated as the change in energy consumption with a change in the energy price and then converted into the change in CO_2 emissions with a change in the price of CO_2, based on an assumed CO_2 content of the energy consumption affected and any process emissions. In energy units, for example, the semi-elasticity of efficiency improvement for railway and domestic flights is similar, but slightly different in CO_2 units due to the assumed different CO_2 content.

Furthermore, *Table 4* shows the calculated price elasticities that apply in the point at expected bases and estimated prices, including tax and emissions allowance in 2030. This means that price elasticities apply to a marginal increase in the price compared to the expected starting point in 2030 before correction for a higher emissions allowance price. The starting point is prices based on Climate Status and Outlook 2021, including the emissions allowance price. As illustrated in equation (5) in *Section 1.2*, the semi-elasticities can be converted into price elasticities at a concrete point on the demand curve (Q,P) on the basis of the price at the given point. This conversion is explained later in this section.

The elasticities, and hence the effects on CO_2 emissions, are likely to be different for an energy tax than for a tax on CO_2 emissions that does not include process emissions. With an energy tax, no switch between fossil fuels is expected. The fossil energy consumption reduced within a sector may also have a lower average CO_2 content under an energy tax than under a CO_2 tax, because a uniform energy tax gives the same tax on all fossil fuels in DKK/GJ, while a uniform CO_2 tax gives the relatively highest tax on the most CO_2-intensive fuels in DKK/GJ. In many of the industries, however, one fossil fuel is dominant, which is why no significant difference between an energy tax and a CO_2 tax is assumed. Furthermore, under an energy tax, process emissions from mineralogical processes, etc. would not be taxed.

With the calculation assumptions stated, a CO_2 tax, including process emissions for mineralogical processes, etc., is assumed to result in a shift towards fossil fuels for ferries and cement. For general process, agriculture excluding agricultural diesel and horticulture, and for fossil fuels for electricity production, a higher CO_2 content of the reduced energy consumption is assumed than for an energy tax, through fossil fuels with the highest CO_2 content getting the largest tax increase. However, the main difference between an energy tax and a CO_2 tax, including process emissions for mineralogical processes etc., concerns mineralogical processes etc., as process emissions represent a large share of emissions.

Table 5 very briefly explains the basis for the determination of the semi-elasticities.

Reconciliation of the technical semi-elasticities to total weighted price elasticity (macro-price elasticity)

With the semi-elasticities used, the overall weighted price elasticity (or "macro-price elasticity") is about -0.5, measured at expected 2030 prices excluding tax and emissions allowance. This is slightly below the estimate of -0.6 from Labandeira et al. (2017).

Table 5
Semi-elasticities and price elasticities for technical effects for industry in the case of energy tax as used in the calculation of overall weighted price elasticity (the macro-price elasticity)

	Technical semi-elasticity (percentage change in PJ for a change in price of 1 DKK/GJ)	Price elasticity (for estimated price before tax and emissions allowance)	Background for elasticity in the case of CO_2 tax
General process (ETS and non-ETS)	1.20	0.7	Gas is used to a large extent, and other fossil fuels only to a limited extent. Therefore, no shift between fossil fuels is expected. Overall, a relatively large shift towards biomass and heat pumps is expected as energy is used to produce heat. For many companies, biomass or heat pumps are likely to be a competitive alternative, even without a tax increase. The distribution between transition to biomass or heat pump is very uncertain. There is also expected to be a potential for efficiency improvements, including through the use of internal surplus heating.
Agriculture etc. excluding agricultural diesel	1.20	0.7	Same as general process, as it is largely the same type of energy consumption.
Agricultural diesel	0.25	0.3	A switch to renewable fuel is not expected to occur until very high tax levels. Furthermore, switching from diesel to other fossil fuels does not seem likely. Furthermore, relatively limited efficiency improvements are expected from an isolated Danish tax, as the market is not large enough to provide tractor manufacturers etc. with an incentive to develop more fuel-efficient engines. Efficiency improvement can thus consist of, for example, better matching of tractor size to needs and lower energy consumption for a given number of horsepower.
Horticulture (ETS and non-ETS)	1.20	0.7	Same as general process, as it is largely the same type of energy consumption.
Mineralogical processes, etc. (cement)	0.77	0.1	A mixture of coal, petcoke and waste is used. A shift from petcoke and coal to gas and biomass is expected. Combinations of fuel prices, CO_2 emissions allowance prices and taxes etc. determine the extent to which it is advantageous to switch to gas or biomass. Switching to a heat pump is not considered relevant, as this involves direct firing at very high temperatures. The potential for efficiency improvement is expected to be relatively high, based on comparisons with energy consumption in cement plants abroad. Furthermore, a reduction of calcium oxide in the cement (which determines the process emissions) is expected, among other things, through the reduction of the clinker proportion, which is replaced by calcined clay.
Mineralogical processes, etc. (non-cement)	0.67	0.3	Gas is used to a large extent, and no switch to other fossil fuels is expected, unlike cement. Efficiency improvements and a shift to biomass are expected.
North Sea	0.70	0.3	Gas is used to power turbines, so no switch to renewable fuels is expected. It is also estimated that the potential for efficiency improvement is of minor magnitude, as is the reduction of flaring. The biggest technical effect is expected to be a switch to electricity. The order of magnitude of this is estimated, among other

			things, on the basis of Norwegian experience, even though a lower switch to electricity is expected than in Norway, as the effect of emissions allowances seems to have been limited in the North Sea, the Danish gas fields are further from land, are smaller and have a shorter expected remaining life.
Refineries	0.83	0.3	Gas is widely used and no switch to other fossil fuels is expected. Relatively high potential for efficiency improvements has been assumed. Furthermore, a switch to biomass is included.
Fisheries	0.40	0.4	Substitution from diesel to other fossil fuels does not seem likely. Fuel switching to renewable fuels is expected to occur only with very large tax increases. Therefore, only a potential for efficiency improvement is expected.
Ferries	0.40	0.4	Fuel switching to renewable fuels is expected to occur only with very large tax increases. There may be a shift from diesel towards electricity, as well as a shift towards gas. In addition, there is potential for efficiency improvements.
Railway	0.30	0.3	Fuel switching from diesel to renewable fuels is expected to occur only with very large tax increases. Switching to other fossil fuels is not considered relevant. Even minor tax increases are expected to lead to some switching to electricity. Thus, from today until 2030, electrification of certain lines is also expected. In addition, there is limited potential for efficiency improvements.
Fossil fuels for electricity production	0.59	0.4	A total conventional price elasticity of -1 (technical effects and structural effects) of energy tax is assumed, which is converted into a semi-elasticity in energy units at an assumed price of DKK 85/GJ (electricity producers' sales price), based on the Climate Status and Outlook 2021. Thus, a semi-elasticity of -1.18 in energy units (1/85 x 100) is used, which in turn is converted to a semi-elasticity of about 0.05 in CO_2 emission units based on an assumed CO_2 content per GJ. This is a computational semi-elasticity, which in turn is computationally equally distributed between technical effect and structural effect, i.e. the technical semi-elasticity amounts to 0.59 in energy units (-1.18/2). The actual effect will, among other things, depend on the effects on waste, where the instruments have not yet been finalised, see *Section 4*. The computational effect used could potentially differ significantly from an effect based on a detailed analysis.
Domestic flights	0.20	0.2	Fuel switching from jet fuel to renewable fuels is expected to occur only with very large tax increases. Switching to other fossil fuels is not considered relevant. The potential for efficiency improvement is expected to be limited.
Total	0.76	0.4	

Note: Elasticities and semi-elasticities are shown as positive numbers, but reflect a decrease in CO_2 emissions with an increase in price. The prices used to calculate the elasticities are based on Climate Status and Outlook 2021, as is the emissions allowance price. It is based on current taxes including the increase of DKK 6/GJ agreed with the Green Tax Reform. Prices are 2021 prices.
Source: Own calculations.

The reconciliation of the sector-specific technical semi-elasticities to the overall weighted price elasticity (macro-price elasticity) is based on semi-elasticities for increases in energy taxes and not CO_2 taxes. This is because the studies underlying the meta-analysis by Labandeira et. al (2017) are estimated to look at increases in energy prices. Thus, a reconciliation based on semi-elasticities of restructuring of energy tax is deemed to best reflect the overall macro-price elasticity. In *Table 5*, the technical semi-elasticities on which the reconciliation is based are given in energy units. They reflect the semi-elasticities in terms of CO_2 emission units, but for cement and ferries they are lower than in *Table 4*, as there is no switching between fossil fuels under an energy tax, and for mineralogical processes etc. they differ, as process emissions are not covered by an energy tax.

In *Table 5*, the technical semi-elasticities are expressed in energy units and converted into a price elasticity. The price elasticity is calculated on the basis of an estimated price excluding taxes and emissions allowances, as opposed to *Table 4*. This is because, as explained above, the macro-price elasticity is calculated on the basis of prices excluding taxes and emissions allowances. *Box 1* explains the conversion from semi-elasticities to price elasticities, and the reconciliation of the semi-elasticities to the overall macro-price elasticity of about -0.5.

In addition to the above semi-elasticities for industry, semi-elasticities for individual and collective heating and technical oil are included in the calculation of the total weighted price elasticity (macro-price elasticity), *see Table 6*.

Table 6
Semi-elasticities and price elasticities of technical effects for individual and collective heating and technical oil upon energy tax

	Technical semi-elasticity (percentage change in PJ for a change in price of 1 DKK/GJ)	Price elasticity (for estimated price before tax and emissions allowance)	Price elasticity (for estimated price incl. tax and emissions allowance)
Individual heating	1.0	0.8	1.5
Collective heating[1]	0.9	0.4	1.0
Technical oil[2]	0.4	0.4	0.4
Total industry, see *Table 5*	0.8	0.4	0.6
Total (macro elasticity)	**0.8**	**0.5**	**0.7**

Note: Elasticities and semi-elasticities are shown as positive numbers, but reflect a decrease in CO_2 emissions with an increase in price. The prices used to calculate the elasticities are based on Climate Status and Outlook 2021, as is the emissions allowance price. The starting point is the applicable taxes. Prices are 2021 prices. 1) For collective heating, a conventional price elasticity of -1 at an energy tax is assumed, which is converted to a semi-elasticity at an assumed price of DKK 110/GJ, based on the Climate Status and Outlook 2021. A semi-elasticity of 0.9 in energy units (1/110 x 100) is therefore used. This is a computational elasticity. The effect is expected to be technical only, i.e. no structural effect. The actual impact will depend, among other things, on the effects on waste, where the instruments have not yet been finalised, *see Section 4*. The computational elasticity used can potentially differ significantly from an effect based on a detailed analysis. 2) Technical oil is oil consumption for non-energy purposes. This includes bitumen, which is used for asphalt, lubricating oils and turpentine.
Source: Own calculations.

Given the considerable uncertainty about the technical elasticities, including the level of the aggregate macro-price elasticity, sensitivities are illustrated in later sections where the technical elasticities used are increased or decreased by 70 per cent. It roughly reflects that the total used macro-price elasticity of approximately -0.5 is lowered to -0.2 or increases to -0.9, which constitutes the two humps in relation to the elasticity of the approximately -0.6 from Labandeira et al. (2017), *see Figure 2*.

Box 1

Conversion from semi-elasticities to price elasticities and reconciliation of price elasticities for the different sectors with the elasticity of total energy consumption

Conversion from semi-elasticity to price elasticity

The semi-elasticity converted to PJ per DKK 100 million at a given point (Q,P) can be converted to a conventional price elasticity at the same point using the formula given in *Section 1.2*:

$$\boldsymbol{\varepsilon = \frac{\Delta Q}{Q} / \frac{\Delta P}{P} = -P\ x\ Z}$$

In addition to the semi-elasticity (Z), the price (P) is included in the calculation of the price elasticity.

If, for example, the semi-elasticity for general process and agriculture etc. (excluding agricultural diesel) of 1.20 PJ per DKK 100 million, *see Table 5*, is taken as a base, this corresponds to a price elasticity of approximately -0.7 at the expected Danish price of their fossil energy consumption in 2030 excluding taxes and emissions allowances of, in round figures, an estimated average of approximately DKK 60/GJ:

$$\boldsymbol{\varepsilon = -P\ x\ Z = \ -60\ \frac{DKK.}{GJ} x\ 1.2 \frac{PJ}{DKK\ 100\ million} = -60\ \frac{DKK\ million}{PJ} x\ 1.2 \frac{PJ}{DKK\ 100\ million} =}$$

$$\boldsymbol{-60\ x\ 1.2 \frac{1}{100} = -0.7}$$

Alternatively, if the price elasticity is calculated on the basis of the expected price including taxes and emissions allowances in 2030, roughly estimated at an average of around DKK 85/GJ, the semi-elasticity would correspond to a price elasticity of around -1.0 (calculated as -(85 x 1.20/100)).

Reconciliation of the technical semi-elasticities to total weighted price elasticity (macro-price elasticity)

When the sector-specific semi-elasticities are reconciled to the total weighted price elasticity (macro-price elasticity), a price excluding taxes and emissions allowances is used. This is because the price elasticity of about -0.6 for total energy consumption, see Labandeira et al. (2017), is found at prices that are typically lower than those in Denmark, given that Denmark has exceptionally high taxes, and now emissions allowance costs, compared to countries in general, including the US and Asia, etc.

Therefore, the total weighted price elasticity (macro-price elasticity) is calculated on the basis of estimates of Danish prices without tax and emissions allowance, as an approximation of international price levels over the last 25 or 50 years. This is associated with uncertainty.

The calculation of the weighted average for total energy consumption (macro-price elasticity) includes the semi-elasticities for industry, *see Table 5*. In addition, semi-elasticities for heating and technical oil are included, *see Table 6*. Semi-elasticities for transport are not included, except for transport included in industry, *see Table 5*. In Labandeira et al. (2017), however, the -0.6 is calculated including price elasticities from transport.

The reconciliation is also made at the expected base in 2030. A basis has been used before correction for the higher emissions allowance price, i.e. the basis from Climate Status and Outlook 2021, consistent with prices from Climate Status and Outlook 2021, just as the semi-elasticities are set based on Climate Status and Outlook 2021. This basis reflects, other things being equal, the relatively high Danish price level including taxes and emissions allowance. Thus, it does not reflect the size or composition of the base in the different areas that would apply in the absence of taxes and emissions allowances (i.e. the approximated base at international prices), which constitutes an additional uncertainty.

Specifically, the weighted average for the total energy consumption (the macro-price elasticity, which is the percentage change in quantity over the percentage change in price) is calculated by changing the tax by DKK 1/GJ for all sectors. The total change in volume is calculated on the basis of the technical semi-elasticities. This is plotted against the total base to find the percentage change in volume. The total price change corresponds to the immediate revenue. This is held against the total value of the basis (price x basis for each sector) to find the percentage change in price.

With the sector-specific semi-elasticities and price assumptions used, the weighted average for total energy consumption (macro-price elasticity) is about -0.5.

The constant semi-elastic curve does not allow a full technical switch to renewable energy and/or electricity. This means that the fossil basis and CO_2 emissions cannot be reduced to zero. However, there is likely to be a "backstop technology", i.e. a technology that leads to a full switch from fossil fuels to this technology. For mobile sources, such as agricultural tractors, domestic flights and fishing vessels, this could be in the form of PtX products or HVO biodiesel, for example, and for stationary installations in, for example, general processing, where energy is used to produce heat, it could be a transition to direct electricity.

Backstop technologies are expected to become profitable only at very high tax levels and thus at very high CO_2 tax rates. When the backstop technology comes into play - i.e. at what tax increase a switch to this technology is initiated - will vary between sectors, depending on the backstop technology, future price conditions, taxes on the sector's fuels, etc. There is a lot of uncertainty about future price conditions. At the same time, it is likely to vary between companies etc. when backstop technology becomes profitable. Therefore, a modelling of the backstop technology's phasing out of fossil fuels will, other things being equal, be over an interval.

Such technologies are not considered in the first interim report - however, for cement, CCS is possible, *see Section 2*. It is assumed that CCS for cement will start at a tax level of DKK 600/tonne of CO_2 and phase out 90 per cent of the remaining base on a linear basis until a tax level of DKK 700/tonne[3, 4]. The structural industry effect is assumed to interact with the technical effect[5].

The approach used for determining technical effects is based on a top-down approach with empirical correlations between prices and consumption of energy, combined with an assumption on the functional form of the demand curve. However, there are no empirical analyses of these correlations (elasticities) for the specific Danish tax bases. When determining the semi-elasticities at sector level, the basis is therefore also assessments of the relevant technologies and fuels of the individual sectors as well as efficiency improvement opportunities, and the expected price ratios between the various technologies (bottom-up assessments) have been looked at. However, there is considerable uncertainty about the actual price ratios between technologies in the future and hence about the level of taxation at which a given technology will be profitable. Similarly, when a given initiative becomes

[3] At a emissions allowance price of approximately DKK 750/tonne CO_2 in 2030, it reflects an assumed cost level for CCS for cement of between DKK 1,350 and 1,450/tonne CO_2, *see Section 2*.

[4] It is assumed that CCS/BECCS captures 90 per cent of a given amount of CO_2 emissions, with a proportion of CO_2 seeping out in the process, *see Section 2*.

[5] At tax levels above 600 DKK/tonne, the technical effect becomes linear, while the structural effect is constantly semi-elastic. The overall demand curve thus becomes a mixture of a linear curve and a curve with constant semi-elasticity. In the cases where the backstop is relevant – i.e. in models where the tax on cement is higher than 600 DKK/tonne, which is only the case for models with a bottom rebate – the demand curve is approximated from the 600 DKK/tonne to a piecewise linear curve. "Pieces"/intervals of DKK 10/tonne are used, which means that the approximation is very close to the non-approximated curve.

profitable will vary between companies due to individual circumstances, and companies have different expectations of future price conditions, etc. Therefore, these estimates are not reflected in so-called Marginal Abatement Costs (MAC) curves, but are "smoothed" via the functional form of the demand curve and reflected in the slope of the demand curve. The semi-elasticities should thus also be interpreted to some extent as probabilities of transition. This is the case, for example, for the semi-elasticity of transition to electricity in the North Sea, which implies that even a limited tax increase will give rise to a limited transition to electricity. However, a switch to electricity is more likely to happen in larger "jumps". Thus, the technical effects estimated in the first interim report may differ from estimates based on an approach that relies more on the use of MAC curves. Particularly in the case of major restructuring of taxes, the different approaches can lead to substantial differences in results. As mentioned above, regardless of the methodology chosen, there is a high degree of uncertainty associated with the calculated effects, as major restructuring of taxes are far beyond the basis of experience.

1.3.3. Impact on the industry structure

The structural effect consists of the following main effects:

a. *Increased cross-border trade*
b. *Displacement of production from CO_2-intensive companies to non-CO_2-intensive ones, including relocation of production*

The semi-elasticities used for the structural effect are shown in *Table 7* (same as in *Table 3)*. Furthermore, the methodology used to calculate the structural effect is briefly described. As regards the effect of the shift in production, see point b. above, a methodology has been used in which the tax burden is held up against the gross domestic product at factor cost. Departures from this general approach have been made for some areas. This is the case, for example, for fisheries and the North Sea, where intramarginal earnings (resource rents) are to be expected, and therefore lower semi-elasticities have been used. This includes, for example, agricultural diesel, where a tax is expected to be primarily reflected in lower land values, and domestic flights where there is no international competition.

The structural semi-elasticity is significantly higher for cement than for the other sectors, which can be attributed to the high CO_2 intensity of the sector compared to the gross domestic product at factor cost. The semi-elasticities for mineralogical processes etc. (non-cement) and refineries are similarly also relatively high, while for railway and agricultural diesel no structural effects are assumed.

Furthermore, *Table 7* shows the calculated price elasticities that apply in the point at expected base and estimated prices including tax and emissions allowance in 2030. This means that price elasticities apply to a marginal increase in the price compared to the expected starting point in 2030 before correction for a higher emissions allowance price. The starting point is prices based on Climate Status and Outlook 2021, including the emissions allowance price.

Table 7
Semi-elasticities for structural effects and price elasticity for price incl. tax and emissions allowance

	Price elasticity (for price incl. tax and emissions allowance)	Semi-elasticity (percentage change in CO_2 by a change in the price by DKK 1/tonne)	Calculation method
General process (ETS and non-ETS)	0.4	0.03	Tax burden divided by gross domestic product at factor cost multiplied by elasticity of -2. General process, agriculture (excluding agricultural diesel) and horticulture are considered together, so the semi-elasticity is the same.
Agriculture etc. excluding agricultural diesel	0.4	0.03	Tax burden divided by gross domestic product at factor cost multiplied by elasticity of -2.
Agricultural diesel	-	-	An increased tax burden of e.g. DKK 100 million is probably less than 1 per cent of the value of arable farming measured as a gross domestic product at factor cost with EU subsidy. The economic rent in agriculture is approximately DKK 10 billion at approximately DKK 4,000/ha. No major change in the industry structure of the tax can therefore be expected, which is mainly passed on in lower land values.
Horticulture (ETS and non-ETS)	0.4	0.03	Tax burden divided by gross domestic product at factor cost multiplied by elasticity of -2.
Mineralogical processes, etc. (cement)[1]	2.4	0.52	Tax burden divided by gross domestic product at factor cost multiplied by elasticity of -2.
Mineralogical processes, etc. (non-cement)[1]	0.8	0.09	Tax burden divided by gross domestic product at factor cost multiplied by elasticity of -2.
North Sea	0.1	0.01	Tax burden divided by total production costs multiplied by elasticity of -1. A lower elasticity than the equivalent of tax burden divided by gross domestic product at factor cost multiplied by elasticity of -2 is used, as for the North Sea intramarginal earnings (resource rent) are estimated.
Refineries	1.0	0.10	Tax burden divided by gross domestic product at factor cost multiplied by elasticity of -2.
Fisheries	0.8	0.06	Effect consists of cross-border trade effect and effect due to reduction in fishery The cross-border trade effect must be expected to make up the majority of the effect. In the case of a decline in fishery, the elasticity is expected to be lower than the tax burden divided by gross domestic product at factor cost multiplied by the elasticity of -2, as only part of the tax burdens Danish fisheries. In addition, fisheries are regulated by emissions allowances, so part of the adjustment is likely to be through the emissions allowance price rather than activity.
Ferries	0.3	0.02	The semi-elasticity is summarily determined. It can include both activity reduction and potentially cross-border trade effects depending on how a tax is designed.
Railway	-	-	No structural shifts.
Fossil fuels for electricity production	0.6	0.02	It is assumed that half of the total computational effect used is structural and the other half technical. See *Table 5* and note to *Table 4*.

Domestic flights	0.2	0.01	For domestic flights, it is assumed that almost 1 GJ or DKK 80 of aviation fuel is used for a domestic flight, while an average fare of DKK 400/trip is assumed, i.e. the aviation fuel cost is about 20 per cent of the fare. Assuming a conventional elasticity of -1 with respect to fuel consumption, the conventional elasticity becomes -0.2 (0.2 x -1) due to less activity when aviation fuel prices increase.
Total	1.7	0.15	

Note: Elasticities and semi-elasticities are shown as positive numbers, but reflect a decrease in CO_2 emissions with an increase in price. Semi-elasticities with several decimal places are used for the model calculations. Calculation of semi-elasticities based on tax burden in relation to the gross domestic product at factor cost is based on companies' accounts, emissions allowance statistics and figures from Statistics Denmark. The aim is to take into account the variation in CO_2 intensity in relation to the the gross domestic product at factor cost between companies in different sectors. The prices used to calculate the point elasticities are based on the Climate Status and Outlook 2021, as is the emissions allowance price. It is based on current taxes including the increase of DKK 6/GJ agreed with the Green Tax Reform. General processing, agriculture (excluding agricultural diesel) and horticulture are considered together and an average price for these industries is used to convert semi-elasticity to the price elasticity. Prices are 2021 prices. 1) The point elasticity is calculated on the basis of a price that is a weighted average of the price of process emissions (the emissions allowance price) and the price of fuel-related emissions.
Source: Own calculations.

In the following, there is a further explanation of the calculation method as regards the method that takes as a starting point tax burden held up against gross domestic product at factor cost.

Regarding a. Increased cross-border trade

The effect of cross-border trade, excluding transport, is relevant for fisheries and may also be relevant for ferries[6]. The 2017 *Afgifts- og tilskudsanalysen på energiområdet* (The tax and subsidy analysis in the energy sector) examined cross-border trade effects on fisheries. These studies indicate that the cross-border trade effects on fisheries can potentially be significant, which is reflected in the structural effects underlying fisheries.

Regarding b. Displacement of production

A CO_2 tax will reduce Danish production of goods associated with high CO_2 emissions (and vice versa for activities associated with low CO_2 emissions), including via shifts in Danish foreign trade. The extent of CO_2 reductions resulting from a change in the composition of production depends on whether or not Danish companies can pass on the extra production costs in their selling prices (and possibly pass them on in commodity prices, although this will probably only apply in a few cases).

The degree of pass-through *b* depends on the magnitude of the demand and supply elasticities in the following way:

$$(1) \quad Degree\ of\ pass\text{-}through\ b = \frac{e^s}{e^s + \left\{(1-a)\frac{\varepsilon^S}{a} + \frac{\varepsilon^D}{a}\right\}}$$

where e^s is the elasticity of supply of Danish production, ε^D is the price elasticity of demand in the world market, and ε^S is the elasticity of producers in the rest of the world, while *a* denotes the share of Danish firms in the global market. The expression shown is derived in *Appendix 1*.

If the elasticity of supply e^s is high, and the elasticity of demand ε^D is moderate, while Danish companies have a large market share (i.e. *a* is close to one, e.g.

[6] Danish fisheries, for example, can buy more fuel or offload fish abroad, and foreign fisheries can buy less fuel and offload fish in Denmark through higher taxation. For ferries, it could potentially also become attractive to refuel in other countries, e.g. Germany or Sweden, even if the routes are in Denmark.

because it is a "domestic market business"), the degree of pass-through *b* will be close to one. The prices Danish companies sell at will then rise roughly in line with the tax. The companies' sales will then be reduced to an extent that predominantly reflects demand's sensitivity to the higher market price.

For firms/sectors in international competition, the demand elasticity $\left\{(1-a)\frac{\varepsilon^S}{a}+\frac{\varepsilon^D}{a}\right\}$ could be (potentially very) high, basically because the world market is large relative to the Danish economy (i.e. *a* is small). Then, the degree of pass-through *b* will be close to zero, i.e. there is low degree of pass-through. When the tax cannot be passed on, the tax will immediately burden companies' profits, which will lead to an adjustment via lower Danish supply.

How much Danish production is reduced in this case depends on how much Danish production is no longer profitable at the higher production costs. It is basically determined by the slope of the supply curve, i.e. the elasticity of supply e^s.

A significant part of Danish production, which is particularly heavily burdened by a Danish CO_2 tax because it is highly energy-intensive (e.g. cement, oil refining, food industry, building materials), must be expected to be exposed to a high degree of international competition. This argues for a low pass-through of the tax in the selling prices of the companies concerned and, thus, that the price sensitivity of Danish supply is driving the volume response.

Overall, the contribution to lower CO_2 emissions is through changes in the industry structure and foreign trade:

$$(2)\quad Relative\ change\ in\ Danish\ production = \frac{\Delta Y}{Y} = -\frac{1}{\frac{1}{e^S}+\left(\frac{1}{(1-a)\frac{\varepsilon^S}{a}+\frac{\varepsilon^D}{a}}\right)}\frac{\Delta t}{p}$$

Where p is the world market price, t is the Danish tax, i.e. $p-t$ is the Danish producer price, and Δt is the change in Danish tax. For example, if the market share of Danish firms (i.e. *a*) is quite small, this would suggest that the change in Danish CO_2 emissions via a change in industry structure is predominantly driven by the elasticity of supply. The expression shown is derived in *Appendix 1*.

How large are the price elasticities of supply and demand?
There is considerable literature on ***demand elasticities*** in foreign trade, and their importance for, e.g., short- and medium-term macroeconomic adjustment paths has been discussed for many years.

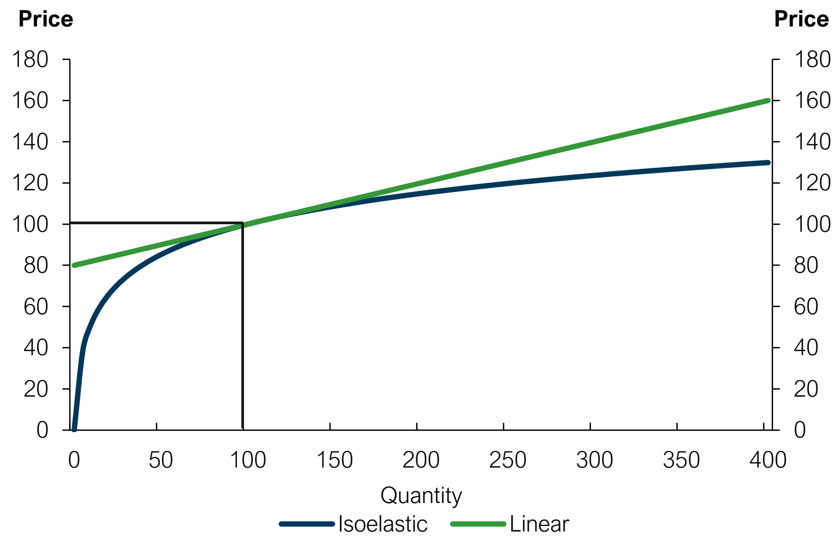
In *Finansredegørelse 2014* (Economic Report 2014), chapter 5, the importance of price elasticities in foreign trade is looked at for the effects of, for example, pension reforms. Elasticities of around -2½ to -5 are used here, based on a summary correction of the relatively low external trade elasticities in ADAM (multiplied by 2½). The analysis also refers to a number of other, relatively recent studies, which indicate somewhat higher price elasticities of around -3 to -11.

As far as ***the elasticity of supply*** is concerned, no empirical evidence is available in the same way as for demand sensitivity.

In order to identify a rough order of magnitude that can be anchored in Danish data, *Figure 3* below can be used as a starting point. The figure shows two supply curves, namely a linear curve and a curve with constant elasticity. A quantity of 100 is offered at a price of 100 under both the isoelastic and linear supply curves.

The supply curve at aggregate level is a horizontal addition of the supply curves of the different companies and therefore reflects the marginal costs of the companies. It should be stressed that the calculations shown are examples that give an impression of some very rough orders of magnitude under the two "polar" assumptions of linearity and constant elasticity, respectively.

Figure 3. Illustration of linear and isoelastic supply curves



The area under the supply curve to the point (100,100) represents the total cost, the area above represents the surplus, and the sum of the two areas represents the production value. For example, if the supply curve is linear, the elasticity of supply at a given point can be calculated as:

$$(3) \quad e^s = \left(\frac{production\ value}{surplus}\right) \cdot 1/2$$

If the supply curve is isoelastic, the elasticity of supply at a given point can be calculated as:

$$(4) \quad e^s = \left(\frac{production\ value}{surplus}\right) - 1$$

The practicality of these two expressions is that they can be used – using national accounts data – to calculate estimated supply elasticities consistent with Danish data for the production value of industry and the composition of factor income (reflected in profits) under the two different assumptions about the shape of the supply curve. These expressions are derived in *Appendix 1*.

On the basis of national accounts figures from Statistics Denmark, it can be calculated that Danish industry's profits in the period 1966-2019 have averaged about

11.8 per cent of the production value[7]. For a linear supply curve, this corresponds to a point elasticity of about 4.2 (1/0.118 x ½), while for an isoelastic curve it corresponds to an elasticity of about 7.5 (1/0.118 – 1). Profits are here expressed as gross profits, i.e. profits before depreciation of capital but after remuneration of employees[8, 9]. On average, this indicates an elasticity of the order of 5½, or somewhat above the demand elasticities used in the analysis in *Finansredegørelse 2014* (Economic Report 2014) referred to above.

As with the shape of the demand curve, *see Section 1.2*, the shape of the supply curve is not known, which is a source of uncertainty in its own right. The supply curve is probably neither linear nor isoelastic. For example, isoelastic curves are characterised by passing through the point (0,0), i.e. even at a very small price, a (albeit very small) quantity of a given good will be produced. This is unlikely to be realistic.

Moreover, the elasticity of supply will be different in the short and long term. The calculation above is based on a time horizon of short/medium term, corresponding to the fact that it roughly reflects a profit margin calculated on the basis of gross profit. In the longer term, a concept of profit that does not include depreciation of capital will be more relevant. Based on Danish industry's net profit, i.e. profit after depreciation, which in the period 1966-2019 amounted to about 6.3 per cent of output, this corresponds to a point elasticity of about 7.9 for a linear supply curve, while for an isoelastic curve it corresponds to an elasticity of about 14.9, and on average just over 11.

In the very long term, the elasticity of supply could be even higher, as the profit after depreciation includes normal rate of return. In the longer term, it must be assumed that a return equivalent to the alternative rate of return will be achieved. In the very short term, the elasticity of supply will be lower, as it will be the marginal costs that will have to be covered, reflecting a surplus measured as gross residual income.

It must be emphasised that – as the range of the supply elasticities shown above shows – these are not precise estimates but indicative rough orders of magnitude. However, these indications – together with the fact that a relatively low pass-through rate is to be expected – suggest that supply-side adjustments will account for a large share of the impact of a Danish CO_2 tax on the emissions of industries in the medium and long term. And the simple computational examples illustrate that the magnitude of relevant supply elasticities can be potentially significantly larger than typically used foreign trade price elasticities.

Based on the above, a weighted price elasticity of -5 for relative change in Danish production has been used. On the face of it, this is slightly below the estimates

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[7] Profits are here and in the following calculated on the basis of figures from the StatBank Denmark table NABP69 and NABB69.

[8] In the national accounts statistics, see table NABP69, the calculation of profits does not deduct the remuneration of self-employed. In the calculation, the profit is reduced by an estimate for this remuneration. The estimate is based on figures for hours worked, see table NABB69, and on the assumption that the hourly rate for a self-employed person is the same as the hourly rate for a wage earner.

[9] The pharmaceutical industry currently has very high profit margins, which affects the average profit margins for the industry relatively quite a lot. Looking at industry excluding pharmaceuticals, the profit margin averaged 10.4 per cent over the period 1966-2019. For a linear supply curve, this corresponds to a point elasticity of about 4.8, while for an isoelastic curve, it corresponds to an elasticity of about 8.6. To the extent that there are above-normal profits in the pharmaceutical industry at present, it can be argued that profits for the industry excluding pharmaceuticals should rather be considered when estimating elasticities.

described above. However, this should be seen in the light of the fact that changes in the industry structure may already be included to some extent in the estimated technical effects. Thus, part of the average macro-price elasticity of around -0.6 reported in Labandeira et al. (2017) can probably be explained by a (national) reduction in energy demand via higher prices, and not only via efficiency improvements, etc. Other things being equal, this speaks for a slightly lower contribution from industry structure, given the assumptions used regarding the technical effect.

Rescaling elasticity from production value to gross domestic product at factor cost

Specifically, the calculation method for the shift of production from CO_2-intensive to non-CO_2-intensive firms is based on the immediate tax burden on the gross domestic product at factor cost and an elasticity of -2, i.e. the structural effect is calculated as:

$$(5)\quad \frac{\Delta Y}{Y} = \left(\frac{tax\ burden}{production\ value}\right) \cdot -5 = \left(\frac{tax\ burden}{gross\ domestic\ product\ at\ factor\ cost}\right) \cdot -2.$$

$\Delta Y/Y$ indicates the percentage change in output. The term (tax burden/production value) in equation (5) reflects the term $\frac{\Delta t}{p}$ in equation (2) multiplied by the production quantity, Y, in both numerator and denominator, while the -5 reflects the term $1/(\frac{1}{e^S} + \left(\frac{1}{(1-a)\frac{\varepsilon^S}{a} + \frac{\varepsilon^D}{a}}\right))$ in equation (2).

The elasticity of -2 with respect to the gross domestic product at factor cost corresponds to the above-mentioned elasticity of -5, which must be seen in relation to the production value. The conversion is based on the fact that the gross domestic product at factor cost represents about 40 per cent of the output of Danish manufacturing (i.e. the -2 is calculated as -5 x 0.4).

For Danish industry as a whole, the gross domestic product at factor cost has accounted for just over 30 and just under 40 per cent of the production value since 1965, although with an apparent slight upward trend in recent years. Across sectors, there is a tendency towards clustering around 40 per cent. Using the sector breakdown used here, only refineries are significantly below 40 per cent, with the gross domestic product at factor cost relative to production value ranging from about 0 to 15 per cent, and food, beverage and tobacco, where it ranged from 20 to 25 per cent. For the pharmaceutical industry it has been above, especially in recent years, *see also footnote 9*.[10]

When introducing a tax on CO_2 emissions from industry, it seems reasonable to calculate the effect on Danish production from the tax burden in relation to the gross domestic product at factor cost (or net income payments to factors of production) since the behavioural effect, loosely formulated, must be expected to reflect the fact that it must continue to be profitable to use labour and capital in industry for the remaining activity. As mentioned above, the rescaling is really only relevant for refineries, where the structural effects without this rescaling would be incredulously small.

It can be argued that the tax burden should be related to the profits of each industry. However, the profit margin in a given year varies significantly across sectors,

[10] Calculated on the basis of figures from the StatBank Denmark table NABP69.

just as it varies considerably between years within the individual sector. However, what determines the future impact of a tax on output is the expected profits, not the current one. In addition, figures for individual sectors may reflect internal organisational issues etc. in larger groups rather than real economic ones.

For these pragmatic reasons, the contribution to the CO_2 impact of changes in the industry structure is calculated by taking the tax burden as a proportion of the gross domestic product at factor cost.

Conversion from conventional price elasticities to semi-elasticities
The estimates of demand elasticities known from the literature, as discussed above, are in the nature of conventionally defined elasticities, where the relative change in quantity is related to the relative change in price. They are converted to semi-elasticities, since a curve with constant semi-elasticities is used, see earlier. Equation (5) can be written as:

$$(6)\quad \frac{\Delta Y}{Y} = \left(\frac{tax\ burden}{gross\ domestic\ production\ at\ factor\ cost}\right) \cdot -2 = \frac{\Delta P \cdot Y}{gross\ domestic\ production\ at\ factor\ cost} \cdot -2$$

This in turn can be rewritten to:

$$(7)\quad z = \frac{\Delta Y}{Y} / \Delta P = \frac{Y}{gross\ domestic\ production\ at\ factor\ cost} \cdot -2$$

That is, the semi-elasticity, which is the percentage fall in output when the price changes by one unit, can be calculated as output divided by the gross domestic product at factor cost multiplied by the elasticity of -2. Production and reduction in production can be translated into CO_2 emissions or reduction in CO_2 emissions based on the assumed CO_2 content of the production that is reduced. The semi-elasticity in CO_2 emission units can thus be calculated as CO_2 emissions divided by gross domestic product at factor cost multiplied by -2.

Since there is a lot of uncertainty about the semi-elasticities used for structural effects, sensitivities are illustrated in later sections where the semi-elasticities used are increased or decreased by 70 per cent.

1.4. Correction of the base as a result of higher emissions allowance price

The CO_2 base for industry is essentially based on the energy balance from Climate Status and Outlook 2021. However, a correction is made to the basis in 2025 and 2030, as the Ministry of Finance's latest projection of the emissions allowance price expects a much higher emissions allowance price going forward than the emissions allowance price used for the Climate Status and Outlook 2021. A higher emissions allowance price must be expected to reduce the CO_2 emissions of industry covered by the emissions allowance compared to the estimate in Climate Status and Outlook 2021.

In the Climate Status and Outlook 2021, a emissions allowance price in 2025 and 2030 of about DKK 300 and DKK 350 per tonne, respectively, was used. The latest projection estimates a emissions allowance price of about DKK 650/tonne in 2025 and about DKK 750/tonne in 2030, i.e. the estimate is increased by about DKK 350/tonne in 2025 and about DKK 400/tonne in 2030 (2022 prices).

The correction of the base for the sectors covered by the emissions allowance, i.e. general process (ETS), horticulture (ETS), mineralogical processes etc. (cement and non-cement), the North Sea, refineries, fossil fuels for electricity production and domestic flights is modelled as a tax increase of about DKK 350/tonne CO_2 in 2025 and about 400/tonne CO_2 for these sectors using the CO_2 base based on the Climate Status and Outlook 2021. The functional form of the demand curve has been assumed as described above, i.e. a demand curve with constant semi-elasticity, using only the technical semi-elasticities, *see Table 4*. Structural effects are therefore not included. The effect in 2025 is also assumed to be affected by the higher emissions allowance price in both 2025 and 2030, following the principles outlined in *Section 1.6. Phasing in behavioural effects*.

The assumption of technical transition alone is due to the fact that the increase in the emissions allowance price includes all companies covered by emissions allowances in the EU. Therefore, it is to be expected that companies will be able to pass on the higher emissions allowance price in their sales price to a large extent and that this will only change the competitiveness of Danish companies to a minor extent compared to other companies in the EU. This assumption of no structural effects is associated with very high uncertainty, as countries outside the EU are by nature not subject to increased emissions allowance costs, just as differences in CO_2 intensity between Danish companies and other companies in the EU can give rise to structural effects.

The higher emissions allowance price will also be the basis for the Climate Status and Outlook 2022. However, it will be included together with a large number of other changes, and for this reason, among other things, the base used in 2030 in the Expert Group's first interim report must, other things being equal, be expected to differ from the base in Climate Status and Outlook 2022.

1.5. Modelling of base deductions

Two models are outlined in the first interim report in which a base deduction is given in the CO_2 tax. The base deduction is intended to reduce the impact of the tax on the industry structure. The starting point is that an activity-based base deduction is given, i.e. it is linked to the company's production, without a concrete decision being taken on exactly how it is set up. It is thus assumed that the base deduction can be designed to maintain the full incentive of the tax for technical transition at the margin but reduce the structural effect.

An activity-based base deduction can be structured in several ways, e.g. the base deduction can be given for output measured in units produced or measured in value produced (value added). An activity-based base deduction will increase the activity targeted by the subsidy and, depending on what it is targeted at, it will lead to distortions in the behaviour of companies, *see Section 4.5 of the report*. In the case of a base deduction for the number of units produced, the base deduction will provide an incentive to produce more units, and in the case of added value, it will give the incentive to increase the added value.

Specifically, the effect of base deductions is modelled by downscaling the semi-elasticities used for structural effects. The semi-elasticities are scaled down by the size of the base deduction. For example, for a tax increase up to a rate of 750

DKK/tonne with a base deduction of 86 per cent, the effect of the tax and base deduction is modelled by scaling down the industry structural elasticity to 86 per cent of the original and calculating a tax increase up to 750 DKK/tonne. The demand curve thus has a different slope, but the same functional form. This will increase the share of technical reductions compared to industry structural reductions for a given CO_2 reduction.

For a given tax increase, the introduction of a base deduction by the method used will reduce the CO_2 reduction compared to the tax alone. This means that a further increase in the tax rate is needed to achieve the same CO_2 reduction as with the tax increase alone. This will increase the socio-economic cost of a given CO_2 reduction. Unintended distortionary effects of the base deduction are not taken into account, which in isolation suggests that the socio-economic costs are underestimated, as well as for the CO_2 effect of a tax increase combined with a base deduction.

The method does not attempt to provide a precise estimate of the impact of introducing an activity-based base deduction in practice, but rather to illustrate the impact of a (not precisely defined) activity-based base deduction. This will require more analytical work, including determining the precise nature and magnitude of the distortionary effect of the different types of base deduction. However, the calculations illustrate that with a base deduction, some socio-economically relatively inexpensive reductions are not implemented, and in return - to achieve a given CO_2 reduction - more expensive reductions must be implemented via increased tax rates. Therefore – and since not all distortions are included – the exact size of the concrete shadow prices has to be interpreted with caution.

1.6. Phasing in behavioural effect

The semi-elasticities used should be understood as "long-run" elasticities, see earlier. Elasticities can be found in the economic literature for both the short and long term, but the lengths of the "short term" and "long term" are rarely specified and are subject to uncertainty.

When determining the phasing in, it is assumed that 1/3 of the total semi-elasticity Z (technical and structural effect) is a short-term behavioural effect, while 2/3 of the total semi-elasticity is a long-term behavioural effect. It is based on the relationship between the short-term and long-term effects, *see Labandeira et al. (2017)*, where the short-run and long-run elasticities are estimated to be of the order of about -0.2 and about -0.6, respectively, on average, *see Box 2.*

Box 2

Phasing in behavioural effects - short and long run elasticities

The CO_2 reduction from tax rate increases is a combination of a long-term effect, which is a gradual response to the final tax rate, and a short-term effect, which is an immediate in-year response to a tax increase.

The short-term effect represents adjustments that can be introduced immediately, e.g. ferries can slow down to reduce fuel consumption.

Long term is not defined in terms of years, but in terms of the time it takes to replace other factors of production with which the product is used. Energy is rarely used directly to produce a good or service, but with other factors to produce other goods or utilities in households. In the case of machinery, the long term is likely to be between 5 and 15 years, with installations probably having a lifespan of around 30 years, while insulation has a lifespan equivalent to the lifespan of the home, which is often over 100 years. As time goes on, the total price effect will probably increase, where the annual contribution to this will be decreasing. Estimates of long-run effects are therefore likely to underestimate long-run effects on average and to be more uncertain in most cases. Another reason for a possible underestimation of long-term effects may be that the estimation period is too short. This will automatically apply if the effect of a recent price change is examined.

When determining the phasing in, it is assumed that 1/3 of the total semi-elasticity Z (technical and structural effect) is a short-term behavioural effect, while 2/3 of the total semi-elasticity is a long-term behavioural effect. It is based on the ratio between the short-term and long-term effects, see Labandeira et al. (2017), where the short-run and long-run elasticities are estimated to be of the order of about -0.2 and about -0.6, respectively, on average.

It is also assumed that an agreement on the first phase of Green Tax Reform can be concluded in 2022, but that the transition from energy tax to CO_2 tax will come into effect in 2025.

Example with tax increase in one specific year

The short-term elasticity

The short-term effect of 1/3 of the final behavioural effect occurs in the year when the tax rate increases. For example, if an agreement is adopted in 2022 and enters into force in 2025, the short-term effect will be felt in 2025. For example, if it does not enter into force until 2030, the short-term effect will be felt in 2030.

The long-run elasticity

The long-term effect of 2/3 of the final behavioural effect is phased in gradually from the adoption of an agreement until its entry into force, but at least over 5 years. If an agreement is adopted again in, say, 2022 and enters into force in 2025, i.e. there are less than 5 years from adoption to entry into force, the long-term effect is phased in linearly from 2022 until 2026, when the effect is fully phased in. For example, if the tax increase only enters into force in 2030, the effect is phased in linearly over the period from 2022 until 2030, when the effect is fully phased in.

Example with linear tax increases every year until 2030

Instead of a tax increase being introduced in one specific year, gradual tax increases could be introduced, e.g. equal annual incremental increases until 2030 (linear tax increases). This will gradually increase the existing differentiated tax rates towards a uniform rate in 2030.

An example can be given where it is assumed that an agreement is adopted in 2022 and that this agreement includes a linear tax increase to be phased in from 2025 to 2030.

The short-term elasticity

The short-term effect of 1/3 of the final behavioural effect occurs in the year when the tax rate increases. As the tax is increased linearly over the 8-year period from 2023 to 2030, the short-term effect is similarly phased in linearly over the period, reaching its full impact in 2030.

The long-run elasticity

The long-term effect of 2/3 of the final behavioural effect is phased in linearly over the 9-year period from the adoption of the agreement in 2022 to 2030, when the effect is fully phased in.

The long-term macro-price elasticity of technical effects of about -0.5 is thus phased in gradually over 5 years, but until the tax enters into force if it enters into force more than 5 years after adoption. The same is true for the structural effect. By phasing in the tax gradually towards 2030, the long-term macro-price elasticity regarding technical effects is thus phased in over the 9-year period from 2022 to 2030. Correspondingly, the structural effect is phased in over the 9-year period.

2. Calculation principles for CCS/BECCS

The Expert Group's first interim report includes models where, in addition to changes in taxes, a subsidy scheme/pool is introduced that is assumed to support capture and storage of CO_2 from fossil and biogenic emission sources (CCS/BECCS).

The first interim report does not provide a comprehensive model set-up that includes both taxes and subsidies in general. However, the effects of a subsidy pool are modelled consistently with the approach used for taxes, assuming that the incentive for CCS/BECCS is the same whether a CO_2 tax of DKK 1/tonne of CO_2 is applied or a subsidy of DKK 1/tonne of CO_2 is given.

In the models presented in the first interim report, fossil emissions are initially subject to a CO_2 tax, which is assumed to be saved by CCS, and the tax instrument therefore provides an incentive for CCS. The biogenic emissions are not subject to CO_2 tax, and a regulatory incentive for BECCS, therefore, includes a subsidy. The models in the report include pools targeting BECCS (negative emissions) and pools including both CCS/BECCS.

2.1. Subsidy/tax incentive for CCS/BECCS

A pool to support capture and storage of CO_2 from fossil and biogenic emission sources (CCS/BECCS) is considered relevant for a number of industrial, CHP and waste plants.

The assessment of whether CCS/BECCS is appropriate for given sources is based on a comparison of estimates of technical costs associated with CCS/BECCS and the benefits of installing CCS/BECCS. The benefit is primarily determined by the amount of pool funds received, as well as the tax and emissions allowance payment that can be saved for the source by storing the CO_2. The saved tax and emissions allowance payment depends on the amount of fossil emissions from the source, as the biogenic emissions are both tax and emissions allowance exempt. Based on estimates of technical costs, fossil emissions and expected emissions allowance price, a correlation between tax/subsidy needs and CO_2 reductions is calculated.

The tax/subsidy needs and CO_2 reduction potential are thus determined on the basis of bottom-up calculations of the costs and savings from CCS/BECCS. As there is considerable uncertainty about these calculations, including the assumed prices etc., the calculations in the first interim report are based on the assumption that a potential of approximately 3.3 million tonnes can be realised with an initial subsidy level (subsidy requirement without tax contribution) increasing from DKK 600/tonne to DKK 1,000/tonne of CO_2, *see below.*

Prerequisites for calculating subsidy needs
It is assumed that subsidy is paid per tonne of CO_2 reduced through CCS/BECCS, so that sources have a permanent incentive to store the CO_2. The pool is also assumed to be offered as a competitive model, where the lowest bid per CO_2 reduction wins the subsidy until the pool is depleted. It is assumed as a starting point that the sources bid in with their actual costs and that there is, thus, no overcompensation.

The estimated tax/subsidy needs have been prepared by the Danish Ministry of Climate, Energy and Utilities on the basis of general calculation examples with general technical costs of CCS/BECCS on individual, selected point sources. In terms of calculation, estimates of the potential of CO_2 reductions that are expected to be realized by CCS/BECCS are distributed among the total costs.

The technical cost estimates cover both fixed costs for investment in capture facilities and infrastructure for transport and storage, as well as variable costs for transport, storage and operation of capture facilities. The technical costs are subject to considerable uncertainty and some general price estimates for CCS/BECCS for various point sources have been used as a starting point, which means that the calculations only cover to a limited extent the heterogeneity that can be expected in practice between point sources when applying CCS/BECCS. However, the costs reflect a certain differentiation between the different point sources in industrial, CHP and waste plants, among others in relation to the fossil share of emissions. That the potential for CCS is handled by phasing in over a span must be seen in the light of the fact that, computationally, it takes into account the heterogeneity that will be expected in practice when allocating pool funds in a model with competition. That is when adding more pool funds, the price of reductions increases.

In order to calculate tax/subsidy needs, the costs are deducted from the gain the plants are estimated to be able to achieve by not having to pay a emissions allowance price for the CO_2 that is reduced via CCS/BECCS. Specifically, *(fossil content x emissions allowance price)* is subtracted from the cost per tonne of CO_2. This is primarily relevant for industry, which has only fossil emissions. In addition, waste plants have a share of fossil emissions. The expected reduction due to *Aftale om Klimaneutral Affaldssektor i 2030 (2020)* (Agreement on Climate Neutral Waste Sector in 2030 (2020)) has been taken into account.

Based on the technical costs and the expected emissions allowance price, the Danish Ministry of Climate, Energy and Utilities estimates that approximately 3.3 million tonnes of reductions via CCS/BECCS can be realised with an initial subsidy level increasing from DKK 600 to DKK 1,000 per tonne of CO_2, i.e. the subsidy level when taxes and possible declining bases due to tax increases are disregarded. In addition, given a significant increase in the expected emissions allowance price in 2030, it is estimated that reductions from CCS for industry will be at the lower end of the range from DKK 600-700 per tonne, due to the fact that emissions from this sector are covered by the allowance system (predominantly fossil), while emissions from waste plants and CHP plants are predominantly biogenic. The total cost of CCS for industry is thus estimated at DKK 1,350-1,450/tonne of CO_2. With an expected CO_2 emissions allowance price in 2030 of approximately DKK 750/tonne of CO_2, there is thus a tax/subsidy need of DKK 600-700/tonne, *see Table 8*.

Table 8
Assumptions about potential as well as cost differential and tax/subsidy needs for CCS/BECCS

	Waste plants and other CHP production (biogenic and mixed emissions)	Industry (fossil emissions)
	- - DKK/tonne of CO_2 (2022 prices) - -	
Tax/subsidy needs	600-1,000	600-700
CO_2 emissions allowance in 2030	175[1]	750
Total costs	600-1,175	1,350-1,450
CO_2 reduction potential in total (before tax increases) 3.25[2] million tonnes		

Note: 1) The CO_2 emissions allowance price of 175 DKK reflects a fossil share of about 20-25 per cent. 2) The 3.25 million tonnes of CO_2 is the reduction potential that can be counted in the shortfall compared to the 70 per cent target. That is effects due to the CCUS pool and pool set aside with FL22 have been corrected. In the event of an increase in taxes, a declining base for CCS is expected. In practice, calculations are set up according to the main models with a tax of DKK 100/tonne for mineralogical processes etc., where the potential is reduced to 2.8 million tonnes.
Source: Danish Ministry of Climate, Energy and Utilities and own calculations.

The potential is beyond the CO_2 reductions estimated to be achieved through CCS/BECCS as a result of previous political agreements in the context of the *Aftale om finansloven for 2022* (Agreement for the Finance Act for 2022) and the CCUS pool agreed in *Klimaaftale for energi og industri mv. 2020* (Climate Agreement for Energy and Industry etc. 2020). The actual aid requirement depends on the tax rate. The higher the tax, the lower the actual subsidy level for fossil emissions must be before CCS is profitable. This does not apply to biogenic emissions, which would be unaffected by a tax increase.

For example, main model 2 in the first interim report provides a subsidy of up to DKK 850/tonne of CO_2. At the same time, a CO_2 tax of DKK 750/tonne is introduced outside the ETS sector (just as the heating taxes are reorganised so that the CO_2 tax has this level), a tax is introduced within the ETS sector of DKK 375/tonne is introduced and a tax on mineralogical processes etc. of DKK 100/tonne. The need for subsidy, and thus the subsidy rate, is calculated as the difference between the tax and the total calculated tax/subsidy need, *see Table 8*. The need for subsidy is thus up to DKK 850/tonne of CO_2 for biogenic waste and up to DKK 100/tonne of CO_2 for fossil waste for heat production, while there will be a derived tax loss of DKK 750/tonne of CO_2 for fossil waste for heat production.

It should be noted that these are very uncertain estimates for both potentials and costs. Thus, there may be plants outside the estimated potential that will find it profitable to install CCS/BECCS at the estimated subsidy needed, just as there may be plants that will step in at a lower subsidy price. Similarly, the price may turn out to be higher than expected. Developments up to 2030 may therefore have a crucial impact on the actual realisation of a given potential.

The establishment of a concrete CCS/BECCS pool will require further analysis. Below it is noted that it may be necessary under state aid law to set off emissions allowances in the aid in order to avoid overcompensation for individual companies.

Uncertainty associated with future regulation

Finally, there is uncertainty associated with future regulation, including future tax levels and the future emissions allowance prices, as well as regulation associated with an alternative use of CO_2. If future regulation and/or market development promotes a PtX market (e.g. in the form of a deployment of pool funds associated with the Danish PtX strategy or blending requirements proposed in FF55), a willingness to pay for CO_2 that exceeds the level of subsidy obtained by storing the CO_2 could potentially arise. Such a scenario would reduce the effects of a CCS/BECCS pool, but conversely free up subsidy funds for other potential reductions.

Other assumptions

In the case of subsidies for CCS/BECCS to industry, it is assumed that a tax increase (and thus an immediate burden) will still lead to both technical transition and a structural effect. The tax payment from a company that receives subsidies for CCS/BECCS can be seen as co-financing, as this reduces the need for subsidies.

It is also assumed that subsidies for CCS/BECCS do not affect the activity included in the projection of the CO_2 base used in the calculations, i.e. that a company receiving CCS/BECCS subsidies does not receive subsidies for any increased production.

It is assumed that CCS/BECCS captures 90 per cent of a given amount of CO_2 emissions from industrial, CHP and waste plants, with a proportion of CO_2 leaking out in the process[11].

For the cost estimates, it is assumed that the lifetime of all plants is 15 years, which corresponds to the estimated lifetime of the plants. Storage infrastructure (such as vessels and pipelines) will also need to be invested in and is assumed to have a lifespan of 30 years. A minimum ROI requirement of 7 per cent has been assumed for the investment costs.

The cost estimates do not include taxes. Among other things, the heating tax is not included for the heat used for the CC system. It is not expected that the use of electricity and heat in CC plants will significantly affect consumer prices for electricity and heat. This is because the CC process is expected to produce equivalent heat that can be fed into the grid. However, the extent to which this will happen depends on regulation. It is estimated that 20 per cent of the heat produced by the CC process can be sold directly into the grid, reducing the cost of capture. The remaining 80 per cent of heat will require upgrading via heat pump before it can be sold, but this is not factored into the cost. If the heat can be sold for more than it costs to upgrade it, this will lower the overall cost of capture.

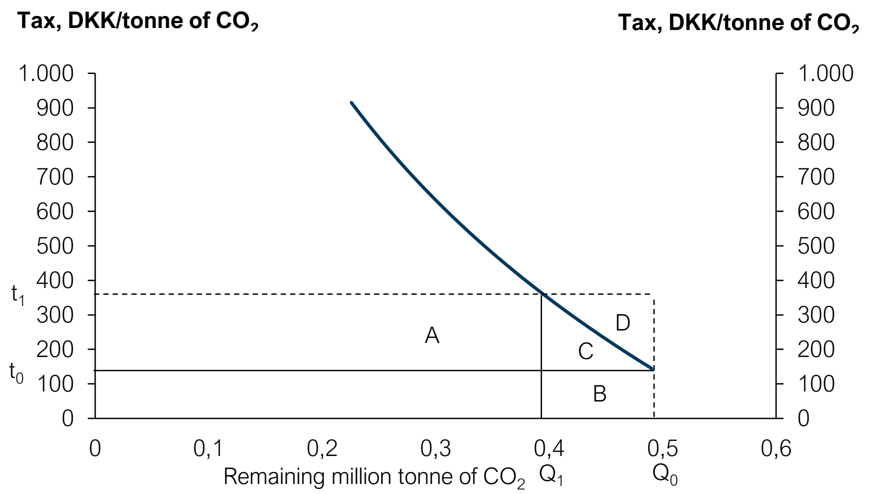
[11] However, a tax can provide an incentive to further improve the CCS plant and thus reduce the amount of CO_2 that leaks out in the process. Thus, there may potentially be a small technical effect that is not included in the calculations. However, this effect is limited, as there is limited scope for improving CC plants. It is also a small part of the base, and the technical effects are a smaller proportion of the total transition.

3. Calculation of revenues, socio-, transition and business economic effects

In addition to CO_2 effects, the first interim report calculates the impact on government finances of CO_2 taxes and the subsidy pool. Furthermore, the total socio-economic cost, the average CO_2 shadow price (i.e. the average socio-economic cost per tonne of CO_2 reduction) or the marginal CO_2 shadow price (i.e. the marginal socio-economic cost per tonne of CO_2 reduction), as well as business economic costs and transition effects on the labour market broken down by sectors.

The calculation of these effects is illustrated on the basis of *Figure 4*, which shows the CO_2 demand curve for ordinary processes within the ETS sector. The CO_2 base (Q_0) amounts to 0.49 million tonne in 2030 at a tax (t_0) of DKK 144/tonne CO_2. With a tax increase up to e.g. 375 DKK/tonne of CO_2 (t_1), the sector reduces its CO_2 emissions by about 0.1 million tonnes to (Q_1).

Figure 4. Illustration of socio-economic costs etc. upon an increase in the CO_2 tax



Source: Own calculations.

Impact on government finances
The impact on government finances is measured partly as the immediate revenue effect and partly as the revenue effect after behavioural response.

The immediate revenue effect corresponds to the tax burden for the unchanged behaviour and is calculated as the increase in the tax in DKK/tonne of CO_2 multiplied by the base (the area A+C+D in *Figure 4*).

Companies etc. change their behaviour as a result of the tax and reduce their fossil energy consumption and thus CO_2 emissions. This results in a derived lower revenue from the energy and CO_2 taxes (the area B+C+D in *Figure 4*, where B represents lower revenue from the existing tax, and C+D represents lower revenue from the tax increase). Furthermore, there will be a static effect, which for businesses amounts to 7.5 per cent of the immediate revenue effect, assuming a spillover in tax on salaries. According to *Section 1.3.3* and *Section 2.4 of the report*, it is largely to be expected that a CO_2 tax on business cannot be passed on in firms' selling prices, but is largely "passed on" in wages. In addition, the supply of labour is affected by the tax, *as described in Section 2.4 of the report*, which further results in a derived lower income.

The immediate revenue effect after static effects and behavioural response is thus made up of the immediate revenue effect minus derived lower revenue from the energy and CO_2 taxes, static effects and labour supply effects.

In addition, for subsidies to CCS/BECCS, there is a government cost corresponding to the amount of the subsidy and derived lower revenue from fossil emissions, *see Section 2*.

Socio-economic costs
The socio-economic cost of raising the tax for a given sector is the sum of the costs and benefits for the sector and the state. It corresponds to the area under the demand curve for CO_2 emissions before the tax increase (Q_0) and after (Q_1) (area B+C in *Figure 4*).

First, the state's revenue effect of the tax is taken into account:

$$State = + \underbrace{A + C + D}_{\text{Immediate revenue}} - \underbrace{B + C + D}_{\text{Behaviour}} = A - B$$

As explained above, the state receives an immediate revenue from the tax increase and a derived tax loss via the changed behavioural response.

Subsequently, the effect of the tax on the given industry is calculated:

$$Sector = - \underbrace{A + C + D}_{\text{Immediate revenue}} + \underbrace{D}_{\text{Transition gain/users' benefit}} = -(A + C)$$

The immediate revenue, which is a gain for the state, is a loss for the sector. However, companies in the sector change their behaviour, e.g. invest in a heat pump or biomass plant or implement energy efficiency improvements, which gives them a benefit compared to the immediate burden (i.e. it reduces their burden). The loss to the sector/companies by behavioural response is thus equal to the revenue by behaviour (A) plus the cost of changing behaviour (C). This switching cost reflects, for example, investments in a heat pump or energy efficiency improvements. Companies will bear the cost of reducing their CO_2 emissions as long as the savings on energy costs including tax are greater than the additional cost. The size of the transition costs for the individual company that changes its behaviour must therefore be expected to amount to between virtually zero and up to the tax increase (for some companies, it is only exactly worthwhile to change behaviour for a given tax increase, because the adaptation costs largely correspond to the tax increase, while other companies would change their behaviour even with a marginal tax increase because the costs are also marginal).

Finally, the total socio-economic cost of the tax can be calculated by summing the impact on government and sector:

$$Socio\text{-}economic\ cost = state + \ sector = (A - B) - (A + C) = -(B + C)$$

The socio-economic cost is thus made up of the state's derived lower revenue (B) as a result of the changed behaviour, as well as the companies' transition costs (C).

The socio-economic cost, represented by the area under the demand curve (C+B), is calculated as an integral having the general solution:

$$Socio\text{-}economic\ cost = \frac{Q_0}{Z}\, x\left(Z \cdot t_0 + 1 - (1 + Z \cdot t_1)e^{-Z\cdot(t_1 - t_0)}\right)$$

where Q_0 corresponds to the base before the tax increase, Q_1 to the base after the tax increase, t_0 to the tax before the increase, t_1 to the tax after the increase and Z to the total semi-elasticity, where $Z = Z_t + Z_s$.

For a given tax increase, the socio-economic cost is calculated according to the above method for each of the sectors concerned.

In addition to the socio-economic cost described above, an increased and extended CO_2 tax has an effect on labour supply, *see Section 2.4 of the report*. The socio-economic cost of changing labour supply is added to the socio-economic cost described above, and thus constitutes the total socio-economic cost of a CO_2 tax.

The average CO_2 shadow price, corresponding to the total average cost per tonnes of CO_2 for all sectors, is made up of this sum divided by the total CO_2 reduction.

The marginal CO_2 shadow price reflects the shadow price of reducing an additional tonne of CO_2. In the event of tax increases, the marginal CO_2 shadow price corresponds to the tax rate per tonne of CO_2 after tax increase plus labour supply effect.

In models where subsidies are provided for CCS/BECCS, the subsidy will have a socio-economic impact in isolation. It is assumed that the subsidy for CCS/BECCS exactly covers the cost of capturing and storing CO_2. This implies that the isolated socio-economic impact of subsidies for CCS/BECCS can be calculated as the size of the part of the subsidy pool that is paid out. The average CO_2 shadow price corresponds to the average subsidy per tonne of CO_2, while the marginal shadow price corresponds to the maximum subsidy rate.

Business economic costs

The economic cost describes the cost imposed on the taxed sectors by the increase in CO_2 taxes. The economic costs have been calculated after adjustment, so that the costs consist of the additional tax payment that the sectors have to pay after they have adjusted their production and reduced their CO_2 emissions (area A in

Figure 4), and of the costs that the sectors have to bear in order to convert their production (area C in *Figure 4*). This can alternatively be formulated as the immediate tax burden (A+C+D) minus the transition gain (D).

In the Expert Group's models, CO_2 emissions are broken down by tax bases, while economic costs are broken down by sectors. The 69-sector grouping from Statistics Denmark is used to distribute the economic costs at sector level. For some of the tax bases in the Expert Group's models, there is a 1-to-1 mapping between the base and the national accounts sectors. This is the case for fisheries and refineries, for example, and for these sectors, the CO_2 base and tax rates for the relevant tax bases will simply be transferred to the industries. For the tax bases "general process (ETS)", "general process (non-ETS)" and "mineralogical processes etc." the CO_2 base and the tax rates must be spread over several sectors. To do this, it is assumed that the tax base "mineralogical processes, etc." is derived from the "glass and concrete industry". This industry is assumed not to pay taxes for general process. In addition, it is assumed that the tax bases for general process originate from the remaining industrial sectors.

Statistics Denmark's data for GreenREFORM is used to allocate the two tax bases for the general process to the sectors, as it is possible to distinguish between ETS-covered and non-ETS-covered CO_2 emissions by sector.

To calculate the burden per employee and the burden in terms of GVA, sector-distributed employment figures and GVA from 2019 from Statistics Denmark have been used. It is thus implicitly assumed that employment and GVA in 2030 are unchanged from the level in 2019.

Transition effects on the labour market
Transition effects on the labour market occur when the industry structure changes in the sector, *see Section 2.4 of the report*.

The transition effects at sector level are calculated in the report using the same method as the structural effects for CO_2 emissions, *see Section 1.3.3*. In order to take into account the large heterogeneity in the companies' CO_2 intensity at industry level, the 20 largest ETS-registered emitters in the industry are taken out of their respective national accounts sector, and the transition effects for these 20 companies are calculated according to the same procedure as for the sectors. Data for employment and GVA in the 20 companies are based on their annual accounts for 2019.

The Danish Economic Councils has also examined the transition effects of tax model 1 for the first interim report of the Expert Group. Results and comparison with the results in *Section 2.4 of the report* can be seen in *Box 3*.

Box 3

Transition effects from the Danish Economic Councils

The transition effects of tax model 1 have also been calculated by the Danish Economic Councils (DØRS), which has assessed the employment effects of a higher CO_2 tax in the context of its 2020 report from the Danish Environmental Economic Council (DMØR). The methodology behind the calculations can be found in the DMØR report[12].

DØRS finds that model 1 entails a change of approximately 2,500 people in the affected sectors with a drop in employment, *see Table 9*. Of these, *Agriculture and Fisheries etc.* and *Mineralogical processes, etc.* account for the majority of the transition, as with the transition effects in *Section 2.4 of the report*.

Table 9. Transition effects for tax model 1 from DØRS

	Number employed	Change	
		Number	Percentage
Agriculture and Fisheries, etc.	66,900	-1,100	-1.6
Utilities	31,500	+0	+0.1
Mineralogical processes, etc.	14,600	-400	-2.8
Other industry	294,800	-0	-0.0
Domestic transport	34,200	-0	-0.0
Sectors with reduced total employment	-	-2,500	-0.4

Note: Employment figures are rounded to the nearest 100 persons. Industries with negative transition effects do not add up to the figures in "Sectors with reduced total employment". This is due to, that the sectors add up to a number of sub-sectors that both have positive and negative transition effect "Sectors with reduced total employment" only add up over the sub-sectors with negative transition effec
Source: DØRS.

There are some data and methodological differences between the transition calculations for DØRS and the calculations in the report, which explains why the transition effects differ from each other. For example, DØRS uses a general equilibrium model, while the calculations in the report are partial. In addition, the report generally uses larger structural effects than DØRS, which is particularly true for agriculture, oil refining, mineralogical processes, etc. and general process. This is partly because cement is separated from other mineralogy etc. in the report's calculations, just as the most CO_2-intensive companies in the general process are also separated from the less CO_2-intensive companies for the purpose of calculating transition effects. Both of these differences draw towards larger transition effects in the report.

[12] The Danish Economic Councils, Economy and Environment 2020

4. Calculation principles for heating

Emissions from heating amount to about 1.9 million tonnes in 2030, of which emissions from individual heating account for about 71 per cent, *see Table 10*. The emissions from individual heating come predominantly from natural gas, while in collective heating they come mainly from fossil waste. Emissions from heating are based on Climate Status and Outlook 2021 and are not corrected for the effects of a higher emissions allowance price.

Table 10
Base for heating in 2025 and 2030

	Base in 2025		Base in 2030	
	Million tonnes CO_2	PJ	Million tonnes CO_2	PJ
Individual heating (incl. city gas)	1.92	32.9	1.37	23.7
- of which, gas	1.66	29.2	1.23	21.6
- of which, oil	0.23	3.1	0.11	1.5
- of which, city gas	0.03	0.6	0.03	0.6
Collective heating[1]	1.27	27.7	0.54	18.3
- of which, gas	0.21	3.6	0.12	2.0
- of which, oil	0.03	0.4	0.02	0.2
- of which, coal	0.16	1.7	0.00	0.0
- of which, fossil waste	0.86	9.2	0.41	4.4
- of which, biogenic waste	0.00	12.8	0.00	11.7
Heat incl. city gas in total	3.19	60.6	1.92	42.0

Note: The base is calculated as CO_2 emissions linked to the burning of fossil fuels. There are no emissions of greenhouse gases other than CO_2 from fossil sources. In addition, there are minor emissions of greenhouse gases other than CO_2 associated with the burning of biogenic fuels, which are not included in the base. In 2030, they are estimated to amount to about 0.2 million tonne of CO_2e, according to the Climate Status and Outlook 2021. There is uncertainty linked to the distribution of greenhouse gases other than CO_2 on fossil fuels or biogenic fuels. All piped gas is accounted for as fossil, as the marginal consumption of piped gas affects the fossil piped gas consumption, as the amount of biogas in the natural gas network is assumed to be a fixed amount. Figures are rounded, therefore totals may not add up. 1) As far as fossil fuels for district heating, the total base for district heating and electricity including waste is allocated to heat and electricity respectively on the basis of current rules on the allocation of the tax base for heat to CHP plants. The split between electricity and heat will depend on the specific model.
Source: Denmark's Climate Status and Outlook 2021 and own calculations

The energy tax on fossil fuels for heating is much higher than the energy tax on commercial fossil fuels for process. There are only plans to change the energy tax towards CO_2 tax and not increases in the overall tax level on heating – i.e. an increase in the CO_2 tax is matched by a relaxation of the energy tax. As the CO_2

content varies between the different fossil fuels, it is not possible to compensate 1:1 for each fuel.

In concrete terms, the reduction in the energy tax is calculated in such a way that the total tax on natural gas (energy tax and CO_2 tax) remains unchanged. If the tax on natural gas remains unchanged, the tax on oil and especially coal and fossil waste (where the CO_2 content per unit of energy is highest) will increase. The more of the energy tax that is shifted from an energy tax to a CO_2 tax, the larger the deviations from current tax levels will be for fuels other than natural gas. With a given increase in the CO_2 tax for industry, where a base deduction may be given for companies covered by emissions allowances, the starting point is that the full increase in the CO_2 tax is restructured, regardless of whether the heat is covered by emissions allowances or not. *Table 11* shows the current energy and CO_2 tax rates, as well as the rates for a change in the CO_2 tax to DKK 750/tonne.

Table 11
Current tax rates on heating and rates for a CO_2 tax of DKK 750/tonne

	Energy tax	CO_2 tax	Total	Energy tax	CO_2 tax	Total
	- - DKK/GJ (2022 prices) - -			- - DKK/tonne of CO_2 (2022 prices) - -		
Current rates						
Natural gas	63	10	73	1,105	179.2	1,284
Oil	63	13	76	851	179.2	1,031
Coal	63	17	80	661	179.2	840
Fossil waste	63	17	80	667	179.2	846
Biogenic waste in mixed loads	63	0	63	"infinite"[3]	0	"infinite"[3]
Waste average (2022)[1]	63	8[2]	71	1,482	179.2	1,662
Waste average (2030)[1]	63	5[2]	68	2,471	179.2	2,650
After restructuring						
Natural gas	30.5	43	73	534	750	1,284
Oil	30.5	56	86	412	750	1,162
Coal	30.5	71	102	320	750	1,070
Fossil waste	30.5	71	101	323	750	1,073
Biogenic waste in mixed loads	30.5	0	31	"infinite"[3]	0	"infinite"[3]
Waste average (2022)[1]	30.5	32[2]	62	717	750	1,467
Waste average (2030)[1]	30.5	19[2]	50	1,195	750	1,945

Note: For conversion between DKK/GJ and DKK/tonne of CO_2, emission factors of 0.057 ton/GJ for natural gas, 0.074 for oil and 0.09529 ton/GJ for coal and 0.09444 ton/GJ for fossil waste are used 1) It is assumed that the fossil share of waste calculated in energy units constitutes 45 per cent in 2022 and 27 per cent in 2030, *see Climate status and projections 2021*. 2) Calculated as the average CO_2 tax in mixed waste with a fossil share of 45 per cent in 2022 and 27 per cent in 2030. 3) As biogenic waste is calculated as CO_2 neutral, the energy tax calculated per tonne of CO_2 becomes infinitely large.
Source: Th Danish Ministry of Taxation, Climate Status and Outlook 2021 and own calculations.

Waste for incineration is often a mixture of fossil and biogenic waste. In the case of mixed waste, the same energy tax is paid for the fossil and biogenic part, but the biogenic part is exempt from CO_2 tax. The shift of the energy tax towards the CO_2 tax implies a relief for biogenic waste mixed with fossil waste, as the energy tax is eased without a counteracting effect from the CO_2 tax. Therefore, a changeover also gives, overall, an immediate lower revenue from heating in 2025 and 2030, i.e. which is generally relaxed.

Only some behavioural effects of restructuring the energy tax to a CO_2 tax on heating have been calculated. A CO_2 reduction from the fossil waste in collective heat has thus been included in the calculation, see below. As regards revenue, it is calculated after automatic return flow and including labour supply effects. Behavioural effects in the form of a shift away from fossil fuels on individual heating have not been calculated and only for calculation purposes with regard to fossil waste.

For individual heating, where the fossil energy consumption is predominantly natural gas, where the rate is kept unchanged, the behavioural effects are expected to be very limited. However, other things being equal, there will be an effect on the remaining oil consumption, for example, in the form of a switch from an oil boiler to a heat pump, via a higher tax. See *Table 10,* however, the oil consumption and CO_2 emissions from this are very small.

As far as collective heat is concerned, by far the largest fossil energy consumption is made up of waste, and in 2030, in addition to this, a little natural gas and a limited amount of oil. However, the largest energy tax base is biogenic waste, *see Table 10*.

A higher tax on fossil waste incineration is estimated to encourage waste incineration plants to receive less fossil waste and possibly separate the fossil waste in mixed waste loads, thus affecting the composition of waste incinerated. A restructuring of the taxes will thereby encourage a reduction in fossil CO_2 emissions from the waste incineration sector. This is further reinforced by the implementation of the agreed capacity adjustment in *Climate Plan for a Green Waste Sector and Circular Economy* from 2020.

However, a relaxed tax on biogenic waste may increase the incentive to incinerate biogenic waste, which is contrary to the intentions of *Climate Plan for a Green Waste Sector and Circular Economy* and Denmark's EU commitment to recycle waste rather than incinerate it.

At present, it is impossible to estimate precisely the CO_2 effects of a restructuring of the heating taxes in the waste area. This is because a number of measures have been adopted in recent years to reduce the emission of CO_2 within the waste sector, which have not yet come into force. The measures relate to EU obligations for the waste sector, capacity adjustment, imports, sorting and recycling targets. The concrete effects of these measures need to be further examined, including the interaction with other regulation. This is considered to be outside the scope of the Expert Group's investigation.

For the first interim report, a technical reduction in CO_2 emissions from fossil waste has been calculated, reflecting the fact that the higher tax on fossil waste encourages the collection of less and the separation of more fossil waste. This technical reduction has been calculated on the basis of the semi-elasticity for collective heating, of approximately 0.9 PJ per DKK 100 million, which has been used when weighing the technical elasticities to the macro-price elasticity, *see Table 6.* Specifically, a semi-elasticity for fossil waste of 0.086 million tonne of CO_2 per DKK 100 million has been used, based on a CO_2 content in fossil waste of 94.44 kg/GJ. The computational effect from fossil waste used can potentially differ greatly from an effect based on a more detailed analysis.

Calculation of heat price changes
Changes in heating prices are calculated as an annual price change including VAT. These are stylised calculation examples, based on a standard house with a heat consumption of 65 GJ and the change in the tax rate per GJ. A full pass-through of the tax change in the price is thus assumed. For a standard house heated with oil, the annual change in heating costs at a CO_2 tax of DKK 750 would be about DKK 800 per year (65 GJ x (86-76) DKK/GJ x 1.25). In practice, heat consumption will vary according to energy standard and size, among other things.

For collective heat, many pay a price based on the combination of heat sources, including for example biomass boilers and heat pumps, which are not affected by the switch. Some illustrative examples of the composition of heat sources have been calculated in the report.

The calculations do not take into account possible heat loss and efficiency.

5. Sensitivity calculations for industry

Sensitivity calculations have been carried out based on the report's tax model 1, where the CO_2 tax for industry is increased to a uniform level of DKK 750/tonne of CO_2 in 2030 with a 50 per cent reduction for the emissions allowance price and with a negative tax for BECCS, as follows:

1. The technical semi-elasticities are reduced and increased by 70 per cent, respectively. It roughly reflects that the total used macro-price elasticity of approximately -0.5 is lowered to -0.2 or increases to -0.9, which constitutes the two humps in relation to the elasticity of the approximately -0.6 from Labandeira et al. (2017), *see Figure 2*. Other assumptions remain unchanged. The CO_2 effects of fixed tax rates are compared with the socio-economic effects of a fixed CO_2 effect.
2. The structural semi-elasticities are reduced and increased by 70 per cent, respectively, corresponding to a reduction and increase of the applied elasticity of 5 to about 1.5 and 8.5, respectively. Other assumptions remain unchanged. The CO_2 effects of fixed tax rates are compared with the socio-economic effects of a fixed CO_2 effect.
3. Effect estimates are used for structural effects for mineralogical processes, etc. and refineries based on a sensitivity analysis, which, among other things, is based on the assumption that the sectors will only produce as long as the profit is greater than their minimum required rate of return. Other assumptions remain unchanged. Only CO_2 effects are compared here.

In the sensitivity calculations, the restructuring of the heating tax has been disregarded, just as the negative tax on BECCS has been disregarded. Below, the results of the central estimate are shown first.

5.1. Central estimate

An increase of the CO_2 tax for industry to a uniform level of DKK 750/tonne of CO_2 with a 50 per cent reduction for the emissions allowance price (corresponding to a rate of DKK 375/tonne) and a negative tax on BECCS is estimated to reduce CO_2 emissions by about 3.5 million tonnes in 2030, using the above methodology and semi-elasticities. In isolation, the tax increases on sectors reduce CO_2 emissions by around 2.9 million tonnes, *see Table 12*. The table does not include the effects of changing the heating tax to the rate of DKK 750/tonne of CO_2, nor does it include the negative tax on BECCS.

The reduction in total CO_2 emissions for industry is largely driven by reductions in mineralogical processes, etc., especially cement, and for refineries, where the bases are large and the semi-elasticities are also high. The reductions from this amount to about 1.9 million tonnes, or almost 70 per cent of the total reductions. A large part of the reductions in these sectors can also be attributed to structural effects.

Table 12
Model 1. Restructuring and alignment of CO_2 tax to DKK 750/tonne CO_2 and 50 per cent reduction for the emissions allowance price in 2030 by central estimate

	Tax rate before transition	Tax rate 2030	Base	Immediate burden	Revenue after behavioural response	CO_2 effect	Of which, technical reduction	Socio-economic cost (factor prices)
	DKK/tonne of CO_2	DKK/tonne of CO_2	Million tonnes CO_2	DKK million	DKK million	Million tonnes CO_2	Share	DKK million
General process (ETS)	144	375	0.49	100	50	-0.1	0.7	30
General process (non-ETS)	323	750	0.66	300	125	-0.2	0.7	120
Agriculture, etc.	264	750	0.70	300	200	-0.1	[0.7-1.0][1]	50
Horticulture (ETS)	91	375	0.02	0	0	0.0	0.7	0
Horticulture (non-ETS)	271	750	0.05	50	50	0.0	0.7	10
Mineralogical processes, etc. (cement)	[0-65][2]	375	1.51	475	0	-1.3	0.1	200
Mineralogical processes, etc. (non-cement)	[0-65][2]	375	0.75	225	125	-0.3	0.3	50
North Sea	0	375	0.99	325	250	-0.2	0.9	30
Refineries	0	375	0.81	275	125	-0.3	0.3	60
Fisheries	0	750	0.25	175	75	-0.1	0.3	40
Ferries	0	750	0.60	400	250	-0.2	0.6	70
Railway	179	750	0.06	25	25	0.0	1.0	0
Fossil fuels for electricity production	0	375	0.28	100	75	0.0	0.5	10
Domestic flights	0	375	0.16	50	50	0.0	0.5	0
Total (including labour supply)			**7.33**	**2.825**	**1,400**	**-2.9**	**0.3**	**930**
Average socio-economic cost (factor prices) DKK 320/tonne of CO_2								

Note: For the model, the current base deduction in the CO_2 tax has been abolished. Revenue effects are rounded to the nearest DKK 25 million and socio-economic costs to the nearest DKK 10 million. CO_2 effect and the share of the technical reduction are rounded to 1 decimal place. Totals may differ from the sum of individual sectors due to rounding. Rates are shown in 2022 prices, while revenue effects are shown in 2022 levels. It is assumed that the taxes are continuously indexed. 1) The interval reflects the technical share for agriculture etc. (excluding agricultural diesel) and agricultural diesel, respectively. 2) The interval reflects the tax on process emissions from mineralogical processes, etc. and the tax on fuel-related emissions, respectively. The tax on fuel-related emissions of DKK 65/tonne of CO_2 reflects the conversion of the DKK 6/GJ agreed in the Green Tax Reform to a CO_2 tax.
Source: Own calculations.

5.2. Changed macro-price elasticity regarding technical effect

In this section, a sensitivity analysis is performed, where the technical semi-elasticities are respectively reduced and increased by 70 per cent. This roughly reflects the fact that the overall macro-price elasticity is lowered to -0.2 and increased to -0.9, respectively, which constitutes the two humps in relation to the elasticity of the approximately -0.6 from Labandeira et al. (2017), *see Figure 2*.

Models are shown where the CO_2 effect or rate is maintained in relation to the main model 1. *Table 13* provides an overview of the models and the CO_2 effects as well as the average socio-economic cost per tonne of CO_2 in 2030 for the various models.

Table 13
Overview of models in the sensitivity analysis for changed technical effect

	Maintained in relation to model 1	**Rate for non-ETS /ETS**	**CO_2 reduction in 2030**	**Sensitivity technical elasticity**	**Average socio-economic cost in 2030**
		DKK/tonne of CO_2	*Million tonnes CO_2*		*DKK/tonne of CO_2*
Model 1 (central estimate)	-	750/375	-2.9	-	320
Model 2a	Same CO_2 effect	948/572	-2.9	Reduced 70 per cent	410
Model 2b	Same CO_2 effect	662/286	-2.9	Raised 70 per cent	280
Model 3a	Same rate	750/375	-2.4	Reduced 70 per cent	330
Model 3b	Same rate	750/375	-3.4	Raised 70 per cent	310

Source: Own calculations.

Appendix 2 shows the detailed results of the sensitivity models.

If the macro-price elasticity is lowered by 70 per cent, the rate must increase by approximately 26 per cent outside the ETS sector and approximately 53 per cent within the ETS sector with maintained CO_2 reduction (model 2a). On the other hand, if the macro-price elasticity increases by 70 per cent, the rate should decrease by about 12 per cent outside the ETS sector and by about 24 per cent inside the ETS sector with maintained CO_2 reduction (model 2b).

The socio-economic cost of DKK 320/tonne, in the central estimate, rises to DKK 410/tonne, with a reduction in elasticity of 70 per cent (model 2a), while it falls to DKK 280/tonne, with an increase in elasticity of 70 per cent (model 2b). If the macro-price elasticity in absolute terms is estimated too high, the actual socio-economic costs of achieving a given reduction will be higher than assumed. On the other hand, if the macro-price elasticity is estimated too low in absolute terms, the actual average socio-economic costs will be lower than assumed. Given the uncertainty, the expected average socio-economic cost is thus higher than the central estimate of DKK 320/tonne CO_2, as the average of DKK 280/tonne and DKK 410/tonne, corresponding to DKK 350/tonne, is higher than DKK 320/tonne. This reflects the fact that the socio-economic cost of doubling a tax more than doubles. The distortion of consumption through higher taxation more than doubles. In addition, the effect on labour supply contributes to a higher socio-economic cost per tonne of CO_2.

However, changes in the socio-economic cost across sectors are also affected by the fact that technical semi-elasticity represents a very different share of total semi-elasticity (technical and structural) in different sectors (it varies between 12 per cent and 100 per cent), which is why a change in semi-elasticity of +/-70 per cent is a very different change in total semi-elasticity for the different sectors. For mineralogical processes, etc., especially cement, and refineries – which largely drive the overall CO_2 effects – structural effects dominate. Thus, a change in the technical semi-elasticity affects the overall elasticity only to a minor extent, and thus also their CO_2 reductions. For other industries, where the technical effect is high, it affects their CO_2 reductions to a greater extent. This affects the composition of CO_2 reductions across sectors, and since there is no equal socio-economic cost per tonne of CO_2 in the different sectors, the overall average socio-economic cost per tonne of CO_2 across sectors is affected.

If the rate of DKK 750/375 tonne is maintained outside and inside the ETS sector, respectively, a reduction of the macro-price elasticity by 70 per cent implies a reduction of the CO_2 effect by about 19 per cent (model 3a). An increase in the macro-price elasticity of 70 per cent implies an increase in the CO_2 effect of about 17 per cent (model 3b). There is no symmetry, partly because the functional form is constantly semi-elastic, partly because of the changing composition of CO_2 reductions across sectors. It can also explain that the socio-economic cost per tonne of CO_2 increases with a reduction in the macro-price elasticity, and decreases with an increase in the macro-price elasticity for a given tax rate. In addition, the labour supply effect increases with a reduction in the macro-price elasticity, which contributes to a higher socio-economic cost per tonne of CO_2, and conversely with an increase in the macro-price elasticity.

5.3. Changed elasticity regarding structural effect

In this section, a sensitivity analysis is carried out, where the structural semi-elasticities are reduced and increased by 70 per cent, respectively, roughly corresponding to an elasticity of 1.5 and 8.5 in relation to the central estimate of 5 in relation to production value (2 per cent in relation to the gross domestic product at factor cost). The sensitivity is also used for the sectors where the method with an elasticity of 2 per cent in relation to the gross domestic product at factor cost is not used, as the uncertainty surrounding the structural effects is also significant for these.

As for the technical effects, models are shown where the CO_2 effect or rate is maintained in relation to the main model 1.

Table 14 provides an overview of the models and the CO_2 effects as well as the average socio-economic cost per tonne of CO_2 in 2030 for the various models.

Table 14
Overview of models in the sensitivity analysis for changed structural effect

	Maintained in relation to model 1	Rate for non-ETS /ETS	CO_2 reduction in 2030	Sensitivity structural semi-elasticity	Average socio-economic cost in 2030
		DKK/tonne of CO_2	*Million tonnes CO_2*		*DKK/tonne of CO_2*
Model 1 (central estimate)	-	750/375	-2.9	-	320
Model 4a[1]	Same CO_2 effect	1,023/647	-2.9	Reduced 70 per cent	520
Model 4b	Same CO_2 effect	645/269	-2.9	Raised 70 per cent	250
Model 5a	Same rate	750/375	-2.0	Reduced 70 per cent	410
Model 5b	Same rate	750/375	-3.5	Raised 70 per cent	290

Note: 1) In model 4a, the tax within the ETS sector exceeds DKK 600/tonne, where the backstop for cement kicks in. This backstop has not been taken into account in the sensitivity calculation.
Source: Own calculations.

Appendix 3 shows the detailed results of the sensitivity models.

Again, as with the sensitivity calculations for the technical effects, given the uncertainty about the size of the effects, the average socio-economic cost will be higher than the central estimate of DKK 320/tonne, as the average socio-economic cost of models 4a and 4b, where the CO_2 effect is maintained by changing the semi-elasticity by -/+ 70 per cent, is DKK 390/tonne.

If the rate of DKK 750/375/tonne is maintained outside and inside the ETS sector respectively, a 70 per cent reduction in semi-elasticity implies a reduction in the CO_2 effect of about 32 per cent (model 5a). An increase in the semi-elasticity of 70 per cent implies an increase in the CO_2 effect of about 18 per cent (model 3b). Increasing structural semi-elasticity by 70 per cent has roughly the same effect on CO_2 emissions as increasing technical semi-elasticity by 70 per cent, whereas reducing structural semi-elasticity by 70 per cent has a much larger effect. As mentioned above, a change in structural semi-elasticity has a major impact on the CO_2 effect from mineralogical processes, etc. (especially cement) as well as on refineries and thus on the overall CO_2 effects.

As with changes in the technical semi-elasticities, changes in the structural semi-elasticities affect the composition of the CO_2 reductions and hence the socio-economic cost per tonne of CO_2 across sectors. Similarly, the labour supply effect affects the socio-economic cost per tonne of CO_2.

5.4. Changed structural effects for mineralogical processes, etc. and refineries

The overall structural effects/shifts in industry are driven to a large extent by the effects of mineralogical processes, etc., especially cement, and refineries, where the base is large and the industry structural semi-elasticities are high, see above. For mineralogical processes, etc. and refineries, an additional sensitivity analysis of the structural effects of these sectors has therefore been carried out, where the structural effects are based on the national accounts of the industries, the accounts of individual companies and an assumption that the sectors will only produce as long as profits are greater than their minimum ROI requirement. The methodology is discussed in more detail in *Appendix 4.*

In this sensitivity analysis, mineralogical processes, etc. are assessed to be less able to scale up their production (due to high capacity costs) and more likely to make a binary decision to shut down or stay in business. This implies that the functional form in the sensitivity analysis is S-shaped rather than convex (as in the constant semi-elasticity method used). For the refineries, the functional form in the sensitivity analysis is concave rather than convex. In both cases, this draws towards lower structural effects at lower tax levels and larger effects at higher tax levels in terms of the methodology used. However, for refineries, the structural effects of the sensitivity analysis are generally lower than those of the methodology used, except for tax levels well beyond those considered in the first interim report, *see Appendix 4*.

If the structural effects from the sensitivity analysis are applied here, it can be seen that it is mainly the CO_2 effect from mineralogical processes, etc. that is affected and that the differences in the structural effects from mineralogical processes, etc. become greater the smaller the tax increases are considered, *see Tables 15 and 16*. *Table 15* shows the differences in CO_2 effects for the tax increase of DKK 750 outside the ETS sector and DKK 375/tonne within the ETS sector, corresponding to a 50 per cent emissions allowance reduction, just like for the other sensitivity analyses, while the difference is shown in *Table 16* for an increase in the CO_2 tax to DKK 100/tonne (without any tax reductions).

Overall, applying the structural effects from the sensitivity analysis would lead to an additional CO_2 effect of the tax model of DKK 750/375/tonne of 0.1 million tonnes in 2030. The isolated difference for the mineralogical processes, etc. represents an additional CO_2 reduction of 0.2 million tonnes, as the probability of cement production shutdown is estimated to be higher based on the assumptions in the sensitivity analysis than under the methodology used in the first interim report. With the tax model of DKK 100/tonne, applying the structural effects from the sensitivity analysis will, on the other hand, reduce the CO_2 effect by 0.4 million tonnes in 2030. Of this, the differences from mineralogical processes, etc. account for 0.3 million tonnes. The lower effect from mineralogical processes etc. is due to the fact that the probability of cement production shutdown is lower in the sensitivity analysis than in the applied method.

Table 15
Model 6. Restructuring and alignment of CO_2 tax to DKK 750/tonne CO_2 and 50 per cent reduction for the emissions allowance price in 2030. Central estimate excluding structural changes for mineralogical processes, etc. and refineries

	Tax rate after restructuring 2030	Increase in 2030	CO_2 effect		
			Central estimate	Case studies	Difference
	- - DKK/tonne CO_2 - -		- - Million tonnes of CO_2 - -		
Mineralogical processes, etc. (cement and non-cement)	375	[310-375]	-1.6	-1.8	-0.2
Refineries	375	375	-0.3	-0.2	0.1
Other industries, central estimate	[375-750]	[375-750]	-1.0	-1.0	0.0
Total			**-2.9**	**-3.0**	**-0.1**

Note: For the model, the current base deduction in the CO_2 tax has been abolished. Totals may differ from the sum of individual sectors due to rounding.
Source: Own calculations.

Table 16
Model 7. Restructuring and alignment of CO_2 tax to DKK 100/tonne of CO_2 in 2030, with no reduction. Central estimate excluding structural changes for mineralogical processes, etc. and refineries

	Tax rate after restructuring 2030	Increase in 2030	CO_2 effect		
			Central estimate	Case studies	Difference
	- - DKK/tonne CO_2 - -		- - Million tonnes of CO_2 - -		
Mineralogical processes, etc. (cement and non-cement)	100	[35-100]	-0.6	-0.3	0.3
Refineries	100	100	-0.1	-0.0	0.1
Other industries, central estimate	[100-323]	[0-100]	-0.1	-0.1	0.0
Total			**-0.8**	**-0.4**	**0.4**

Note: For the model, the current base deduction in the CO_2 tax has been abolished. Totals may differ from the sum of individual sectors due to rounding.
Source. Own calculations.

6. Considerations towards the final report

The above describes the calculation principles of the first interim report. The final report will further review the calculation principles for the areas not covered by the first interim report.

Inter-ministerial work is underway to complete the development of the general equilibrium model GreenREFORM. In the run-up to the final report, work will continue to finalise the model and it will be used in the final report of the Expert Group, as far as possible. The model is expected to be applicable to the areas covered by the first interim report as well as new areas such as non-energy emissions from agriculture. In addition, the model will be able to directly take into account general equilibrium effects, including interaction effects between restructuring of taxes for different sectors. GreenREFORM is briefly described in *Box 4*.

Box 4

Brief description of GreenREFORM

GreenREFORM is a general environmental and climate economic equilibrium model that can evaluate the environmental and climate impacts of economic activity, as well as the economic effects of environmental and climate policy measures. The model is developed by the DREAM model group in collaboration with researchers from the University of Copenhagen, Aarhus University and DTU.

GreenREFORM consists of a main model and a number of sub-models describing sectors of particular importance for climate and environment. The main model is a general equilibrium model describing Denmark's overall economic activity and combining results from the sub-models. Sub-models are being developed for the energy, transport, agriculture and waste sectors.

The model consists of 59 sectors, each of which uses inputs in the form of building capital, machine capital, labour, materials and various types of energy goods, as well as households that benefit from consumption and leisure. There are 27 energy commodities in the model and the energy-related emissions of sectors and households are directly linked to the use of the energy commodities. The non-energy emissions are linked to the use of the inputs that give rise to the emissions. There are 14 types of greenhouse gas emissions and a distinction is made between territorial emissions and emissions from international transport.

Appendix 1. Derivation of equations concerning structural effects

Degree of pass-through and change in domestic output
A domestic export industry, which sells its goods on the world market in competition with foreign producers, is looked at. To simplify the production, a tax *t* on Danish production is considered.

Equilibrium in the "world market" implies:

$$(1) \qquad s(p-t) + S(p) = D(p)$$

Danish production is called *s*, while foreign production is called *S* and demand on the world market (i.e. from both domestic and the rest of the world) is called *D*. The world market price is *p*. Companies are expected to be price takers.
When a (small) tax is introduced on *dt*, it must be applied that:

$$(2) \qquad s'(dp-dt) + S'dp = D'dp$$

Equation (2) can be used to derive an expression for the pass-through of the tax *b*, i.e. the increase in the world price triggered by the domestic tax. It gives:

$$(3) \qquad b \equiv \frac{dp}{dt} = \frac{e^s}{e^s + \left\{(1-a)\frac{\varepsilon^S}{a} + \frac{\varepsilon^D}{a}\right\}}$$

where the elasticity of domestic supply with respect to the net price *p-t* is:

$$(4) \qquad e^s \equiv \frac{ds}{d(p-t)}\frac{p-t}{s}$$

while the elasticity of supply for foreign producers is:

$$(5) \qquad \varepsilon^s \equiv \frac{dS}{dp}\frac{p}{S}$$

and the (numerical) elasticity of demand on the world market with respect to the world market price is:

$$(6) \qquad \varepsilon^D \equiv -\frac{dD}{dp}\frac{p}{D}$$

while *a* denotes the share of domestic firms in the global market, i.e.:

$$(7) \qquad a \equiv \frac{s}{D}$$

The expression in the curly brackets in the denominator of (3) can be understood as the elasticity of demand for domestic production with an increase in the world market price. This effect will reflect the fact that increased world market prices lead partly to lower global demand and partly to increased foreign production. If *a* is small – i.e. if domestic production is only a small part of the global market – then this elasticity will be numerically (potentially very) large.

It should be stressed that both price elasticities and domestic market share are expected to vary across sectors.

The change in domestic production will be:

$$(8) \qquad s'(dp - dt) = s'(b-1)dt = -\,e^s \frac{s}{p}(1-b)dt = -\frac{1}{\frac{1}{e^s} + \left(\frac{1}{(1-a)\frac{\varepsilon^S}{a} + \frac{\varepsilon^D}{a}}\right)} s\frac{dt}{p}$$

In the case where foreign net demand is very price sensitive – for example because the domestic market is quite small compared to the world market – the last term in the denominator of the expression on the far right will be small. In that case, the effect on domestic production will be determined predominantly by the price elasticity of domestic supply.
The expressions (3) and (8) are used in *Section 1.3.3.*

Production value, factor income and elasticity of supply
To the best of our knowledge, there is no empirical knowledge on the elasticity of supply for Danish companies, i.e. the parameter e^s. Instead, some calculation examples can be drawn up, which can be used to identify possible quite rough orders of magnitude under some specific assumptions.

As an estimate for two "polar" assumptions, a linear supply function and a supply function with constant price elasticity have been taken as a point of departure.

Assuming that the supply *s* is *linear* in the price *p*, the supply function can be written as

$$(9) \qquad s = (1 - e^s)s_0 + e^s \frac{s_0}{p_0} p$$

where the parameters of the linear function are chosen such that the conventionally defined price elasticity is e^s when at the price p_0 the quantity s_0 is produced.
Producers' gross operating profit (i.e. gross residual income) in the starting point will then be:

$$(10) \qquad \pi_0 = \frac{1}{2}\left(p_0 - \frac{e^s - 1}{e^s}\, p_0\right) s_0 = \frac{1}{2}\frac{p_0 s_0}{e^s}$$

Which can be used to derive the value of the elasticity of supply that is consistent with (1) the assumption of linear supply and (2) national accounts data for output value $p_0 s_0$ and gross residual income π_0. It gives:

(11) $$e^s = \frac{1}{2}\frac{p_0 s_0}{\pi_0}$$

At constant elasticity, the supply function is:

(12) $$s = (p)^{e^s}$$

or equal to the marginal cost function:

(13) $$p = (s)^{\frac{1}{e^s}}$$

whereby the total variable costs can be calculated as:

(14) $$TVC = \int_0^{s_0} (s)^{\frac{1}{e^s}} ds = \frac{e^s}{1+e^s}(s_0)^{1+\frac{1}{e^s}}$$

Then the gross profit can be written as:

(15) $$\pi_0 = p_0 s_0 - \mathrm{TVC} = \frac{1}{1+e^s}(s_0)^{1+\frac{1}{e^s}} = \frac{p_0 s_0}{1+e^s}$$

which can finally be used to isolate the elasticity of supply:

(16) $$e^s = \frac{p_0 s_0}{\pi_0} - 1$$

The expressions (11) and (16) are used in *Section 1.3.3*.

Appendix 2. Results of the sensitivity models for technical semi-elasticity

Table 2.1
Model 2a. Restructuring and alignment of CO_2 tax to DKK 948/tonne of CO_2 and 50 per cent reduction for the emissions allowance price in 2030 by reducing technical semi-elasticities by 70 per cent with maintained CO_2 reduction

	Tax rate before transition	Tax rate 2030	Immediate burden	Revenue after behavioural response	CO_2 effect	Of which, technical reduction	Socio-economic cost (factor prices)
	DKK/tonne of CO_2	DKK/tonne of CO_2	DKK million	DKK million	Million tonnes CO_2	Share	DKK million
General process (ETS)	144	572	200	125	-0.1	0.4	30
General process (non-ETS)	323	948	425	250	-0.2	0.4	110
Agriculture, etc.	264	948	425	325	-0.1	[0.4-1.0][1]	40
Horticulture (ETS)	91	572	0	0	0.0	0.4	0
Horticulture (non-ETS)	271	948	75	50	0.0	0.4	10
Mineralogical processes, etc. (cement)	[0-65][2]	572	750	-25	-1.4	0.0	270
Mineralogical processes, etc. (non-cement)	[0-65][2]	572	350	175	-0.3	0.1	90
North Sea	0	572	500	400	-0.1	0.7	30
Refineries	0	572	425	175	-0.4	0.1	100
Fisheries	0	948	225	100	-0.1	0.1	50
Ferries	0	948	500	350	-0.1	0.3	70
Railway	179	948	50	25	0.0	1.0	0
Fossil fuels for electricity production	0	572	150	100	0.0	0.2	10
Domestic flights	0	572	75	75	0.0	0.2	0
Total (including labour supply)			**4,125**	**2,150**	**-2.9**	**0.2**	**1,190**
Average socio-economic cost (factor prices)		**DKK 410/tonne of CO_2**					

Note: For the model, the current base deduction in the CO_2 tax has been abolished. Revenue effects are rounded to the nearest DKK 25 million and socio-economic costs to the nearest DKK 10 million. CO_2 effect and the share of the technical reduction are rounded to 1 decimal place. Totals may differ from the sum of individual sectors due to rounding. Rates are shown in 2022 prices, while revenue effects are shown in 2022 levels. It is assumed that the taxes are continuously indexed. 1) The interval reflects the technical share for agriculture etc. (excluding agricultural diesel) and agricultural diesel, respectively. 2) The interval reflects the tax on process emissions from mineralogical processes, etc. and the tax on fuel-related emissions, respectively. The tax on fuel-related emissions of DKK 65/tonne of CO_2 reflects the conversion of the DKK 6/GJ agreed in the Green Tax Reform to a CO_2 tax.
Source: Own calculations.

Table 2.2
Model 2b. Restructuring and alignment of CO_2 tax to DKK 662/tonne of CO_2 and 50 per cent reduction for the emissions allowance price in 2030 by increasing technical semi-elasticities by 70 per cent with maintained CO_2 reduction

	Tax rate before transition	Tax rate 2030	Immediate burden	Revenue after behavioural response	CO_2 effect	Of which, technical reduction	Socio-economic cost (factor prices)
	DKK/tonne of CO_2	DKK/tonne of CO_2	DKK million	DKK million	Million tonnes CO_2	Share	DKK million
General process (ETS)	144	286	75	25	-0.1	0.8	20
General process (non-ETS)	323	662	250	75	-0.3	0.8	130
Agriculture, etc.	264	662	250	150	-0.1	[0.8-1.0][1]	60
Horticulture (ETS)	91	286	0	0	0.0	0.8	0
Horticulture (non-ETS)	271	662	50	50	0.0	0.8	10
Mineralogical processes, etc. (cement)	[0-65][2]	286	350	25	-1.2	0.2	150
Mineralogical processes, etc. (non-cement)	[0-65][2]	286	175	100	-0.2	0.4	40
North Sea	0	286	250	175	-0.2	0.9	30
Refineries	0	286	200	100	-0.3	0.4	40
Fisheries	0	662	150	50	-0.1	0.5	40
Ferries	0	662	350	200	-0.2	0.7	70
Railway	179	662	25	25	0.0	1.0	0
Fossil fuels for electricity production	0	286	75	50	0.0	0.6	10
Domestic flights	0	286	50	25	0.0	0.6	0
Total (including labour supply)			**2,250**	**1,075**	**-2.9**	**0.5**	**810**
Average socio-economic cost (factor prices)	**DKK 280/tonne of CO_2**						

Note: For the model, the current base deduction in the CO_2 tax has been abolished. Revenue effects are rounded to the nearest DKK 25 million and socio-economic costs to the nearest DKK 10 million. CO_2 effect and the share of the technical reduction are rounded to 1 decimal place. Totals may differ from the sum of individual sectors due to rounding. Rates are shown in 2022 prices, while revenue effects are shown in 2022 levels. It is assumed that the taxes are continuously indexed. 1) The interval reflects the technical share for agriculture etc. (excluding agricultural diesel) and agricultural diesel, respectively. 2) The interval reflects the tax on process emissions from mineralogical processes, etc. and the tax on fuel-related emissions, respectively. The tax on fuel-related emissions of DKK 65/tonne of CO_2 reflects the conversion of the DKK 6/GJ agreed in the Green Tax Reform to a CO_2 tax.
Source: Own calculations.

Table 2.3
Model 3a. Restructuring and alignment of CO_2 tax to DKK 750/tonne CO_2 and 50 per cent reduction for the emissions allowance price in 2030 by reducing technical semi-elasticities by 70 per cent.

	Tax rate before transition	Tax rate 2030	Immediate burden	Revenue after behavioural response	CO_2 effect	Of which, technical reduction	Socio-economic cost (factor prices)
	DKK/tonne of CO_2	DKK/tonne of CO_2	DKK million	DKK million	Million tonnes CO_2	Share	DKK million
General process (ETS)	144	375	100	75	-0.1	0.4	10
General process (non-ETS)	323	750	300	200	-0.1	0.4	70
Agriculture, etc.	264	750	300	250	0.0	[0.4-1.0][1]	20
Horticulture (ETS)	91	375	0	0	0.0	0.4	0
Horticulture (non-ETS)	271	750	50	50	0.0	0.4	10
Mineralogical processes, etc. (cement)	[0-65][2]	375	475	25	-1.3	0.0	200
Mineralogical processes, etc. (non-cement)	[0-65][2]	375	225	125	-0.2	0.1	40
North Sea	0	375	325	275	-0.1	0.7	10
Refineries	0	375	275	150	-0.3	0.1	50
Fisheries	0	750	175	100	-0.1	0.1	30
Ferries	0	750	400	275	-0.1	0.3	40
Railway	179	750	25	25	0.0	1.0	0
Fossil fuels for electricity production	0	375	100	75	0.0	0.2	10
Domestic flights	0	375	50	50	0.0	0.2	0
Total (including labour supply)			**2.825**	**1,675**	**-2.4**	**0.1**	**780**
Average socio-economic cost (factor prices)	**DKK 330/tonne of CO_2**						

Note: For the model, the current base deduction in the CO_2 tax has been abolished. Revenue effects are rounded to the nearest DKK 25 million and socio-economic costs to the nearest DKK 10 million. CO_2 effect and the share of the technical reduction are rounded to 1 decimal place. Totals may differ from the sum of individual sectors due to rounding. Rates are shown in 2022 prices, while revenue effects are shown in 2022 levels. It is assumed that the taxes are continuously indexed. 1) The interval reflects the technical share for agriculture etc. (excluding agricultural diesel) and agricultural diesel, respectively. 2) The interval reflects the tax on process emissions from mineralogical processes, etc. and the tax on fuel-related emissions, respectively. The tax on fuel-related emissions of DKK 65/tonne of CO_2 reflects the conversion of the DKK 6/GJ agreed in the Green Tax Reform to a CO_2 tax.
Source: Own calculations.

Table 2.4
Model 3b. Restructuring and alignment of CO_2 tax to DKK 750/tonne of CO_2 and 50 per cent reduction for the emissions allowance price in 2030 by increasing technical semi-elasticities by 70 per cent.

	Tax rate before transition	Tax rate 2030	Immediate burden	Revenue after behavioural response	CO_2 effect	Of which, technical reduction	Socio-economic cost (factor prices)
	DKK/tonne of CO_2	DKK/tonne of CO_2	DKK million	DKK million	Million tonnes CO_2	Share	DKK million
General process (ETS)	144	375	100	50	-0.1	0.8	40
General process (non-ETS)	323	750	300	75	-0.3	0.8	160
Agriculture, etc.	264	750	300	175	-0.2	[0.8-1.0][1]	80
Horticulture (ETS)	91	375	0	0	0.0	0.8	0
Horticulture (non-ETS)	271	750	50	50	0.0	0.8	10
Mineralogical processes, etc. (cement)	[0-65][2]	375	475	0	-1.3	0.2	200
Mineralogical processes, etc. (non-cement)	[0-65][2]	375	225	100	-0.3	0.4	60
North Sea	0	375	325	225	-0.2	0.9	40
Refineries	0	375	275	125	-0.4	0.4	70
Fisheries	0	750	175	75	-0.1	0.5	50
Ferries	0	750	400	200	-0.2	0.7	80
Railway	179	750	25	25	0.0	1.0	10
Fossil fuels for electricity production	0	375	100	75	-0.1	0.6	10
Domestic flights	0	375	50	50	0.0	0.6	0
Total (including labour supply)			**2.825**	**1,175**	**-3.4**	**0.5**	**1,050**
Average socio-economic cost (factor prices)	**DKK 310/tonne of CO_2**						

Note: For the model, the current base deduction in the CO_2 tax has been abolished. Revenue effects are rounded to the nearest DKK 25 million and socio-economic costs to the nearest DKK 10 million. CO_2 effect and the share of the technical reduction are rounded to 1 decimal place. Totals may differ from the sum of individual sectors due to rounding. Rates are shown in 2022 prices, while revenue effects are shown in 2022 levels. It is assumed that the taxes are continuously indexed. 1) The interval reflects the technical share for agriculture etc. (excluding agricultural diesel) and agricultural diesel, respectively. 2) The interval reflects the tax on process emissions from mineralogical processes, etc. and the tax on fuel-related emissions, respectively. The tax on fuel-related emissions of DKK 65/tonne of CO_2 reflects the conversion of the DKK 6/GJ agreed in the Green Tax Reform to a CO_2 tax.
Source: Own calculations.

Appendix 3. Results of the sensitivity models for structural semi-elasticity

Table 3.1
Model 4a. Restructuring and alignment of CO_2 tax to DKK 1,023/tonne of CO_2 and 50 per cent reduction for the emissions allowance price in 2030 by reducing technical semi-elasticities by 70 per cent with maintained CO_2 reduction

	Tax rate before transition	Tax rate 2030	Immediate burden	Revenue after behavioural response	CO_2 effect	Of which, technical reduction	Socio-economic cost (factor prices)
	DKK/tonne of CO_2	*DKK/tonne of CO_2*	*DKK million*	*DKK million*	*Million tonnes CO_2*	*Share*	*DKK million*
General process (ETS)	144	647	225	100	-0.2	0.9	60
General process (non-ETS)	323	1,023	475	175	-0.3	0.9	180
Agriculture, etc.	264	1,023	475	300	-0.1	[0.9-1.0][1]	90
Horticulture (ETS)	91	647	0	0	0.0	0.9	0
Horticulture (non-ETS)	271	1,023	75	50	0.0	0.9	10
Mineralogical processes, etc. (cement)	[0-65][2]	647	850	150	-1.1	0.3	310
Mineralogical processes, etc. (non-cement)	[0-65][2]	647	400	225	-0.2	0.6	80
North Sea	0	647	575	375	-0.2	1.0	70
Refineries	0	647	475	250	-0.3	0.6	90
Fisheries	0	1,023	225	125	-0.1	0.6	50
Ferries	0	1,023	550	325	-0.2	0.8	90
Railway	179	1,023	50	25	0.0	1.0	10
Fossil fuels for electricity production	0	647	150	125	0.0	0.8	20
Domestic flights	0	647	100	75	0.0	0.8	10
Total (including labour supply)			**4,625**	**2,325**	**-2.9**	**0.6**	**1,510**
Average socio-economic cost (factor prices)	**DKK 520/tonne of CO_2**						

Note: For the model, the current base deduction in the CO_2 tax has been abolished. Revenue effects are rounded to the nearest DKK 25 million and socio-economic costs to the nearest DKK 10 million. CO_2 effect and the share of the technical reduction are rounded to 1 decimal place. Totals may differ from the sum of individual sectors due to rounding. Rates are shown in 2022 prices, while revenue effects are shown in 2022 levels. It is assumed that the taxes are continuously indexed. 1) The interval reflects the technical share for agriculture etc. (excluding agricultural diesel) and agricultural diesel, respectively. 2) The interval reflects the tax on process emissions from mineralogical processes, etc. and the tax on fuel-related emissions, respectively. The tax on fuel-related emissions of DKK 65/tonne of CO_2 reflects the conversion of the DKK 6/GJ agreed with the Green Tax Reform into a CO_2 tax.) 3) The tax within the ETS sector exceeds DKK 600/tonne, where the backstop for cement kicks in. This backstop has not been taken into account in the sensitivity calculation here.
Source: Own calculations.

Table 3.2
Model 4b. Restructuring and alignment of CO_2 tax to DKK 645/tonne of CO_2 and 50 per cent reduction for the emissions allowance price in 2030 by reducing technical semi-elasticities by 70 per cent with maintained CO_2 reduction

	Tax rate before transition	Tax rate 2030	Immediate burden	Revenue after behavioural response	CO_2 effect	Of which, technical reduction	Socio-economic cost (factor prices)
	DKK/tonne of CO_2	DKK/tonne of CO_2	DKK million	DKK million	Million tonnes CO_2	Share	DKK million
General process (ETS)	144	269	50	25	-0.1	0.6	10
General process (non-ETS)	323	645	250	100	-0.2	0.6	100
Agriculture, etc.	264	645	250	150	-0.1	[0.6-1.0][1]	40
Horticulture (ETS)	91	269	0	0	0.0	0.6	0
Horticulture (non-ETS)	271	645	50	50	0.0	0.6	10
Mineralogical processes, etc. (cement)	[0-65][2]	269	325	-25	-1.4	0.1	150
Mineralogical processes, etc. (non-cement)	[0-65][2]	269	150	75	-0.3	0.2	40
North Sea	0	269	250	175	-0.1	0.8	20
Refineries	0	269	200	100	-0.4	0.2	40
Fisheries	0	645	150	50	-0.1	0.2	40
Ferries	0	645	350	200	-0.2	0.5	60
Railway	179	645	25	25	0.0	1.0	0
Fossil fuels for electricity production	0	269	75	50	0.0	0.4	10
Domestic flights	0	269	50	25	0.0	0.4	0
Total (including labour supply)			**2,125**	**1,050**	**-2.9**	**0.3**	**720**
Average socio-economic cost (factor prices)	**DKK 250/tonne of CO_2**						

Note: For the model, the current base deduction in the CO_2 tax has been abolished. Revenue effects are rounded to the nearest DKK 25 million and socio-economic costs to the nearest DKK 10 million. CO_2 effect and the share of the technical reduction are rounded to 1 decimal place. Totals may differ from the sum of individual sectors due to rounding. Rates are shown in 2022 prices, while revenue effects are shown in 2022 levels. It is assumed that the taxes are continuously indexed. 1) The interval reflects the technical share for agriculture etc. (excluding agricultural diesel) and agricultural diesel, respectively. 2) The interval reflects the tax on process emissions from mineralogical processes, etc. and the tax on fuel-related emissions, respectively. The tax on fuel-related emissions of DKK 65/tonne of CO_2 reflects the conversion of the DKK 6/GJ agreed in the Green Tax Reform to a CO_2 tax.
Source: Own calculations.

Table 3.3
Model 5a. Restructuring and alignment of CO_2 tax to DKK 750/tonne CO_2 and 50 per cent reduction for the emissions allowance price in 2030 by reducing structural semi-elasticities by 70 per cent.

	Tax rate before transition	Tax rate 2030	Immediate burden	Revenue after behavioural response	CO_2 effect	Of which, technical reduction	Socio-economic cost (factor prices)
	DKK/tonne of CO_2	DKK/tonne of CO_2	DKK million	DKK million	Million tonnes CO_2	Share	DKK million
General process (ETS)	144	375	100	75	-0.1	0.9	20
General process (non-ETS)	323	750	300	150	-0.2	0.9	100
Agriculture, etc.	264	750	300	200	-0.1	[0.9-1.0][1]	50
Horticulture (ETS)	91	375	0	0	0.0	0.9	0
Horticulture (non-ETS)	271	750	50	50	0.0	0.9	10
Mineralogical processes, etc. (cement)	[0-65][2]	375	475	150	-0.8	0.3	150
Mineralogical processes, etc. (non-cement)	[0-65][2]	375	225	150	-0.1	0.6	30
North Sea	0	375	325	250	-0.1	1.0	30
Refineries	0	375	275	175	-0.2	0.6	40
Fisheries	0	750	175	100	-0.1	0.6	30
Ferries	0	750	400	275	-0.1	0.8	50
Railway	179	750	25	25	0.0	1.0	0
Fossil fuels for electricity production	0	375	100	75	0.0	0.8	10
Domestic flights	0	375	50	50	0.0	0.8	0
Total (including labour supply)			**2,825**	**1,750**	**-2.0**	**0.6**	**800**
Average socio-economic cost (factor prices)	**DKK 410/tonne of CO_2**						

Note: For the model, the current base deduction in the CO_2 tax has been abolished. Revenue effects are rounded to the nearest DKK 25 million and socio-economic costs to the nearest DKK 10 million. CO_2 effect and the share of the technical reduction are rounded to 1 decimal place. Totals may differ from the sum of individual sectors due to rounding. Rates are shown in 2022 prices, while revenue effects are shown in 2022 levels. It is assumed that the taxes are continuously indexed. 1) The interval reflects the technical share for agriculture etc. (excluding agricultural diesel) and agricultural diesel, respectively. 2) The interval reflects the tax on process emissions from mineralogical processes, etc. and the tax on fuel-related emissions, respectively. The tax on fuel-related emissions of DKK 65/tonne of CO_2 reflects the conversion of the DKK 6/GJ agreed in the Green Tax Reform to a CO_2 tax.
Source: Own calculations.

Table 3.4
Model 5b. Restructuring and alignment of CO_2 tax to DKK 750/tonne CO_2 and 50 per cent reduction for the emissions allowance price in 2030 by increasing structural semi-elasticities by 70 per cent.

	Tax rate before transition	Tax rate 2030	Immediate burden	Revenue after behavioural response	CO_2 effect	Of which, technical reduction	Socio-economic cost (factor prices)
	DKK/tonne of CO_2	DKK/tonne of CO_2	DKK million	DKK million	Million tonnes CO_2	Share	DKK million
General process (ETS)	144	375	100	50	-0.1	0.6	30
General process (non-ETS)	323	750	300	125	-0.3	0.6	140
Agriculture, etc.	264	750	300	200	-0.1	[0.6-1.0][1]	60
Horticulture (ETS)	91	375	0	0	0.0	0.6	0
Horticulture (non-ETS)	271	750	50	50	0.0	0.6	10
Mineralogical processes, etc. (cement)	[0-65][2]	375	475	-25	-1.5	0.1	180
Mineralogical processes, etc. (non-cement)	[0-65][2]	375	225	100	-0.4	0.2	70
North Sea	0	375	325	250	-0.2	0.8	30
Refineries	0	375	275	100	-0.4	0.2	70
Fisheries	0	750	175	50	-0.2	0.2	50
Ferries	0	750	400	225	-0.2	0.5	80
Railway	179	750	25	25	0.0	1.0	0
Fossil fuels for electricity production	0	375	100	75	-0.1	0.4	10
Domestic flights	0	375	50	50	0.0	0.4	0
Total (including labour supply)			**2,825**	**1,200**	**-3.5**	**0.3**	**980**
Average socio-economic cost (factor prices)	**DKK 250/tonne of CO_2**						

Note: For the model, the current base deduction in the CO_2 tax has been abolished. Revenue effects are rounded to the nearest DKK 25 million and socio-economic costs to the nearest DKK 10 million. CO_2 effect and the share of the technical reduction are rounded to 1 decimal place. Totals may differ from the sum of individual sectors due to rounding. Rates are shown in 2022 prices, while revenue effects are shown in 2022 levels. It is assumed that the taxes are continuously indexed. 1) The interval reflects the technical share for agriculture etc. (excluding agricultural diesel) and agricultural diesel, respectively. 2) The interval reflects the tax on process emissions from mineralogical processes, etc. and the tax on fuel-related emissions, respectively. The tax on fuel-related emissions of DKK 65/tonne of CO_2 reflects the conversion of the DKK 6/GJ agreed in the Green Tax Reform to a CO_2 tax.
Source: Own calculations.

Appendix 4. Sensitivity analysis for mineralogical processes, etc. and refineries

This appendix describes the sensitivity analysis carried out for mineralogical processes, etc. and refineries in order to quantify the structural effects these will have at different CO_2 tax levels. The sensitivity analysis assumes a different functional form for the structural effects than the constant semi-elasticity functional form used in the first interim report. The sensitivity analysis underlines that there is considerable uncertainty about the structural effects for these sectors.

In the first interim report, the structural effects are based on macroeconomic elasticities, *see Section 1.3.3*. In the sensitivity analysis, the structural decision to produce or shut down instead depends on whether a sector's structural profit is higher than its minimum ROI requirement.

The structural profit is estimated for the refineries as the gross domestic product at factor cost minus remuneration of employees and is based on national accounts data from Statistics Denmark. For mineralogical processes, etc., the structural profit is based on the annual reports of companies in cement production, while the structural effects for non-cement are based on the macroeconomic elasticities. In addition, annual reports for selected enterprises have also been used to quantify the split between physical and intangible assets and between production and sales costs in the sectors.

The minimum ROI requirement of the sectors are calculated as the assets of the sectors multiplied by an average minimum ROI requirement percentage, which is based on the average realised return in per cent that the sectors have had over the last 10 years.

Once the structural profit and minimum ROI requirement are known, a normal distribution for the difference between the structural profit and the minimum ROI requirement is then used with standard deviation in the structural profit margin based on 2015-2020[13] and with a mean value of 0. It is thus assumed that sectors will shut down with a 50 per cent probability when structural profit is equal to the minimum ROI requirement.

The sensitivity analysis distinguishes between profits related to production and profits related to sales and distribution. In order to make this distinction, it is assumed that the share of the sectors' profit that can be related to sales and distribution is

[13] For the refineries, 2018 is excluded due to unusually low value added

equal to the share that the costs of sales and distribution make up of the total costs in the sectors.

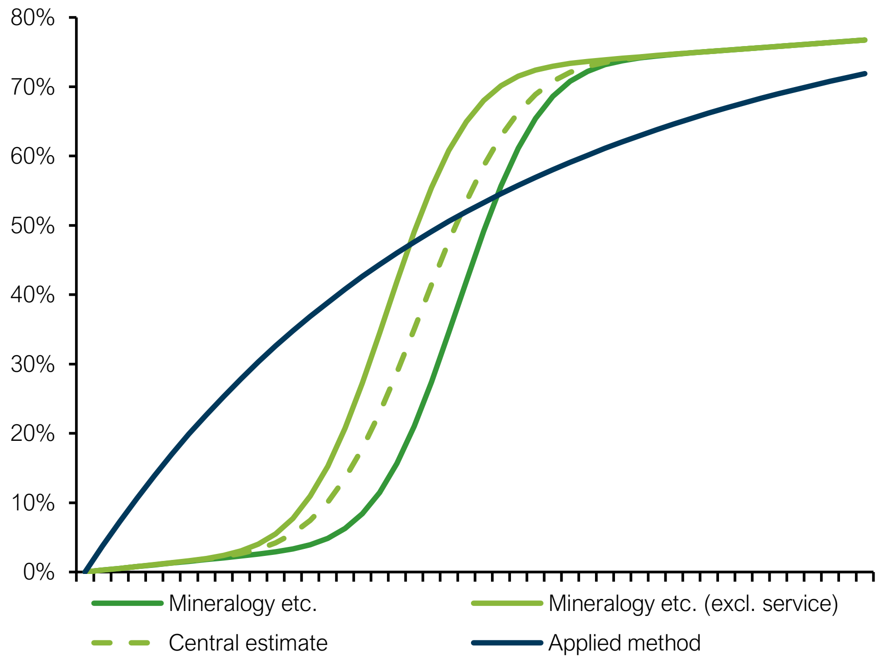
For the sectors, the sensitivity analysis has calculated two scenarios, where the sales and distribution part respectively shut down and stay in business when the sectors' production disappears due to high CO_2 taxes. In addition, a "central" scenario has been calculated, which is an average of the two scenarios. To approximate the minimum ROI requirement from the production part and the sales and distribution part of the sectors respectively, all physical assets are attributed to production, while intangible assets are attributed to sales and distribution. The minimum ROI requirement percentage is assumed to be the same for the production part and the sales and distribution part.

In the sensitivity calculations, sectors will have a certain probability of ceasing production in Denmark, even without CO_2 taxes being imposed on them. To ensure that structural effects are only attributed to tax burdens and not to general economic uncertainty in sectors, Bayesian probabilities of closure beyond the status quo (calculated as ($probab. = \frac{\theta_{tax} - \theta_{starting\ point}}{1 - \theta_{starting\ point}}$), where θ_{tax} is the probability of shutting down at a higher given tax level and $\theta_{starting\ point}$ is the probability of shutting down at the starting point without restructuring of taxes) have been used.

In *Figures 4.1 and 4.2*, the structural effects for both the methodology used in the first interim report and the sensitivity analysis are presented by probability curves. Thus, a structural effect of, say, 10 per cent should not be interpreted as meaning that output falls by 10 per cent, but rather that there is a 10 per cent probability that output will cease.
The sensitivity analysis indicates that the functional form of the probability curve for mineralogical processes, etc. is S-shaped, while for refineries it is concave, *see Figures 4.1 and 4.2*. This is in contrast to the method used, which is based on curves with constant semi-elasticity (convex curves). In both cases, the sensitivity analysis draws towards lower structural effects at lower tax levels and larger effects at higher tax levels in terms of the methodology used. However, for refineries, the structural effects of the sensitivity analysis are generally lower than those of the methodology used, except for tax levels well beyond those considered in the first interim report.

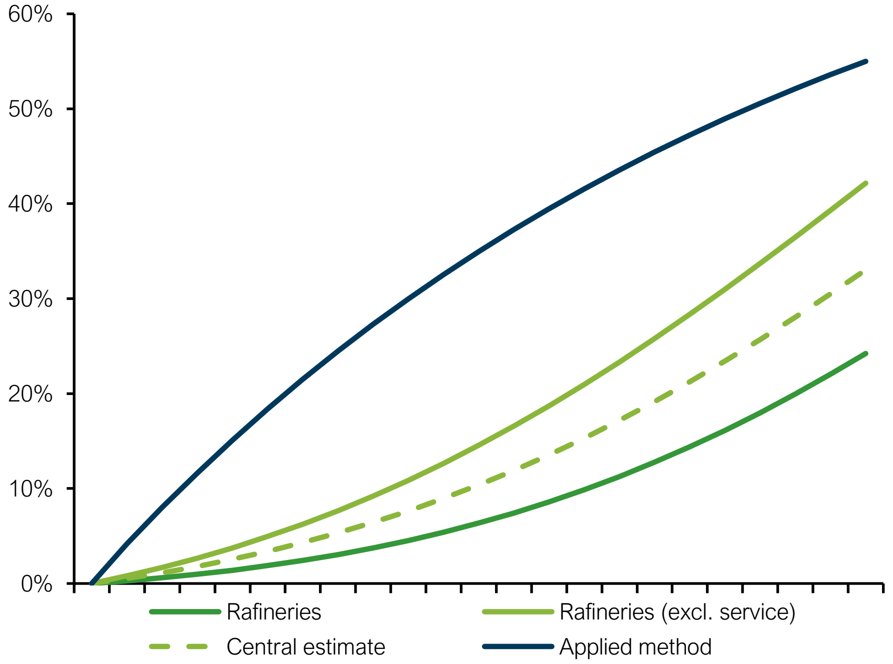
It is generally fraught with great uncertainty at what tax level mineralogical processes, etc. and the refineries move production abroad and continue to distribute in Denmark. The above analysis should be seen in this context.

Figure 4.1
Structural effects of the method used in the first interim report and of the sensitivity analysis for mineralogical processes, etc. for different tax increases



Note: The central estimate of the sensitivity analysis is a simple average of the other two curves.
Source: Own calculations.

Figure 4.2
Structural effects of the method used in the first interim report and of the sensitivity analysis for refineries to different tax increases



Note: The central estimate of the sensitivity analysis is a simple average of the other two curves.
Source: Own calculations.