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EKSPERTGRUPPEN FOR EN
GRØN SKATTEREFORM

Green Tax Reform

Final Report

Contents

Preface

The Expert Group for a Green Tax Reform was established in February 2021.

The members of the Expert Group are:

- Michael Svarer, Professor at the Department of Economics, Aarhus University, Chairman
- Joan Faurskov Cordtz, Partner at PwC
- Susanne Juhl, Chairman and member of the Board
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- Peter Birch Sørensen, Professor at the Department of Economics, University of Copenhagen
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The Expert Group has been tasked with preparing proposals which organise an appropriate regulation set-up that contributes to reducing greenhouse gas emissions within the Danish territory. Based on the guiding principles of the Danish Climate Act, the regulation must, among other things, balance socio-economic efficiency with the aim of preserving existing business structures and minimising carbon leakage risk.

The Expert Group published the first interim report in February 2022. The report primarily focused on emissions from industry etc., and presented models that contributed to significant reductions in greenhouse gas emissions in various ways.

Based on the first report, a broad majority in the Danish Parliament entered an agreement in June 2022 on a green tax reform that contributed to harmonising the taxation of greenhouse gas emissions while supporting the development of climate-friendly technologies.

This report primarily focuses on regulation to help reduce biological greenhouse gas emissions in agriculture.

It's a complicated task. No other country has implemented tax-based regulation of non-energy-related greenhouse gas emissions from agriculture, and thus, the inspiration to find solutions for agriculture must come from elsewhere. This report presents various proposals for regulating agricultural emissions based on the principles characterising the political agreement on a green tax reform for the industry etc.

The Danish climate targets set the framework for the report's ambition level. The Danish Climate Act of 2019 contains a binding target that greenhouse gas emissions from Denmark must be reduced by 70 per cent in 2030 relative to 1990 levels. In addition, Denmark is committed to the EU to fulfil the so-called Effort Sharing

Regulation, which sets requirements to reduce emissions from sources not regulated by the EU ETS. Furthermore, the LULUCF Regulation requires Denmark to fulfil specific requirements for reductions in areas such as forestry and cultivation of agricultural land. The models presented in this report fulfil the reduction requirements defined by the climate targets.

In addition to the members of the Expert Group, Deputy Permanent Secretaries from Ministry of Taxation, Ministry of Finance, Ministry of Climate, Energy and Utilities, Ministry of Environment, Ministry of Food, Agriculture and Fisheries, and Ministry of Industry, Business and Financial Affairs participated in the discussions. We have been serviced by a secretariat consisting of officials from the aforementioned ministries. We thank them for their great dedication and work.

We would also like to take this opportunity to thank the many stakeholders from the Danish business sector and members of the Expert Monitoring Group who have contributed to our work.

Michael Svarer
/Expert Group for a Green Tax Reform, 21 February 2024

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Summary

In this final report, the Expert Group for a Green Tax Reform highlights models for a more uniform regulation of greenhouse gas emissions which were not addressed in the Expert Group's first interim report. Therefore, this report focuses on non-energy-related emissions from agriculture and forestry, which are expected to account for approx. 46 per cent of Denmark's total greenhouse gas emissions in 2030 if climate policy remains unchanged. The report does not present proposals for further regulation of road transport, as the Expert Group operates under the assumption that the government's proposal to increase the diesel tax will be implemented.

The principles of the Expert Group's work and the balance between the considerations of the Danish Climate Act

In accordance with the terms of reference, the Expert Group's analyses are based on the guiding principles of the Danish Climate Act, where the requirement for cost-effectiveness in climate action is central. In order to achieve cost-effective regulation, the incentive for greenhouse gas reduction must, to the greatest degree possible, be uniform across the entire economy. This can be achieved by imposing a uniform tax on all greenhouse gas emissions (measured as CO_2 equivalents reflecting their Global Warning Potential) and subsidising negative emissions at the same rate. However, the Danish Climate Act also contains other considerations, including the intention of counteracting significant paradigm shifts in businesses leading to greenhouse gas leakage, where production and the associated emissions move abroad. According to the Danish Climate Act, the impact of climate policy on social balance and cohesion, i.e. the distribution of the burden between different groups in society, must also be taken into account, and climate policy must adhere to the principle of sound public finances.

The Expert Group's analyses show that it is not possible to fully reconcile all these considerations at the same time through a fully uniform CO_2-eq tax on all emissions from all sectors of society. A fully uniform CO_2-eq tax can certainly ensure a fully cost-effective fulfilment of the Danish Climate Act's target of a 70 per cent reduction in greenhouse gas emissions from Danish territory in 2030 compared to 1990, but it will also lead to significant paradigm shifts in businesses with a high risk of greenhouse gas leakage. Political decision-makers must therefore evaluate the various considerations, which may cause them to refrain from introducing a completely uniform CO_2-eq tax on all emissions. Taking this into consideration, the Expert Group's first interim report on climate regulation of industry etc., in addition to a model with a completely uniform CO_2-eq tax, presented two other models with reduced tax rates for particularly leakage-prone parts of the industry to illustrate the inevitable political trade-offs between cost-effectiveness and minimising paradigm shifts in businesses and carbon leakage.

Main characteristics of the Expert Group's proposal for models for climate regulation of agriculture

In this report, which primarily focuses on reducing greenhouse gas emissions from agriculture, the Expert Group has again chosen to present three different regulatory models that emphasise the considerations of the Danish Climate Act and the terms of reference differently. All three models aim to avoid arbitrary discrimination against agriculture relative to other sectors of the economy. In the Expert Group's model 1, agriculture is equated with other industries outside of the EU ETS, which implies a CO_2-eq tax of DKK 750 per tonne of CO_2-eq in 2030. In the Expert Group's proposal for model 2, agriculture is equated with the companies within EU ETS, since model 2 taxes agricultural emissions at an effective rate of DKK 375 per tonne of CO_2-eq in 2030, while model 3 involves an effective tax rate of DKK 125 per tonne of CO_2-eq in 2030 on livestock, thus equating animal agriculture with the leakage-prone industrial companies within mineralogy.

The Expert Group's proposal for model 1 emphasises socio-economic cost-effectiveness, but implies a significant reduction in agricultural production, especially in cattle farming. The expected decrease in production leads to a relatively high risk of carbon leakage. Model 2 emphasises on replacing CO_2-eq reductions achieved through production decline with reductions from measures of a more technological nature that reduce carbon leakage, but are costlier in socio-economic terms. Model 3 places even greater emphasis on minimising the decline in production through additional technical effects but involves an even higher socio-economic cost, a significant annual burden on government finances, and greater uncertainty about the achievability of technological reductions.

All three models are designed so that, with a phase-in from 2027, which in combination with initiatives outside the scope of the Expert Group's work are estimated to deliver on the 70 per cent target of the Danish Climate Act and Denmark's climate commitments in the Effort Sharing Regulation. The models are expected to reduce CO_2-eq emissions in 2030 of around 2.4-3.2 m tonnes from the agriculture and forestry sector. The models are also estimated to provide significant reductions after 2030. Increased afforestation and wetland restoration of carbon-rich agricultural land (e.g. drained peatlands), which are included in all three models, contribute an additional 1.2 m tonnes of CO_2-eq reduction in 2035 and 2.7 m tonnes annually from 2045 onwards relative to the effect in 2030.

The models presented should be seen in light of the fact that the estimated reductions necessary for achieving the 70 per cent target in 2030 has been reduced as a result of the implementation of the revised EU Emissions Trading System Directive, the political agreement on green aviation and the government's proposal to increase the diesel tax. Together, these measures are estimated to reduce emissions by approx. 1.1 m tonnes CO_2-eq in 2030. Furthermore, a partial correction for the new peatland maps is estimated to reduce emissions by 2 m tonnes of CO_2-eq in 2030. The starting point for the Expert Group's calculations in relation to meeting the 70 per cent target in 2030 is thus that the remaining reduction need amounts to approx. 2.5 m tonnes of CO_2-eq.

Emissions from agricultural biological processes and farm-related activities

The Expert Group's proposal for tax models for agriculture includes three main groups of greenhouse gas emissions:

1. Emissions from livestock. Emissions come primarily from cattle and pigs but also from other livestock, including chickens, ducks, sheep, goats, horses, deer, lambs, and pheasants.
2. Emissions from spreading manure and agricultural lime on fields. Here, manure can be regulated either by tax or by restructuring direct agricultural subsidies.

3. Emissions from carbon-rich agricultural land.

Livestock is by far the largest source of emissions in agriculture. Therefore, all of the Expert Group's proposed models include an effective tax on emissions from livestock that corresponds to the CO_2-eq tax rate in the industry etc. to which agriculture is equated, i.e. DKK 750, 375 or 125 per tonne of CO_2-eq depending on the chosen model. Emissions from manure on fields are regulated with a tax or by restructuring the hectare subsidy to a subsidy for reduced fertiliser use, both with a marginal incentive of DKK 750 per tonne of CO_2-eq, corresponding to the tax rate on companies in the industry etc. that are currently not regulated under the EU ETS.

The taxation and subsidy rate for reduced manure usage are based on calculations of the activities on the individual farm. These calculations are made using the emissions factors used in Denmark's official national emissions inventory to the EU and the UN, which also forms the basis for monitoring Denmark's fulfilment of the Danish Climate Act's 70 per cent target and EU commitments. The inventory takes the fact that emissions from different types of livestock are different and depend, among other things, on the type of housing and how fertiliser and slurry are handled in the stables and storage facilities into account. Furthermore, the calculated emissions are reduced when a company implements measures to reduce emissions from animals and slurry containers etc., if these measures are approved and included in the national emissions inventory.

In this context, the relevant authorities must contribute to the reduction effect and expansion of new measures being documented as quickly as possible such that these are included in the national emissions inventory. The calculation of the emissions from the individual farm can be based to a considerable extent on information that farmers are already obliged to report to the livestock register and in connection with the nitrogen regulation. Therefore, the Expert Group assesses that it is possible to implement a tax and subsidy model that takes the differences in emissions from the individual sources in agriculture used in Denmark's emissions inventory into account.

Afforestation and set-aside of carbon-rich agricultural land

Carbon removal through afforestation is a measure with a relatively low socio-economic cost. The Expert Group has therefore chosen to include subsidies for afforestation (a negative tax) in all the models. The subsidy is determined based on the farmer's calculated cost of afforestation. The initiative in the Expert Group's models is estimated to establish 250,000 hectares of new forest via a subsidy of DKK 92,000 per hectare of forest. This is expected to contribute to reductions of 0.1 m tonnes of CO_2 in 2030, increasing to 2.1 m tonnes of CO_2 in 2045. This furthermore fulfils the government's ambition to establish 250,000 hectares of new forest in Denmark.

As for emissions from carbon-rich agricultural land, all of the Expert Group's models include a tax of DKK 10 per tonne of CO_2-eq from 2030 combined with subsidies for the costs of wetland restoration of carbon-rich agricultural land. The combination of taxation and subsidisation should be seen in the light of the fact that the regulation should increase the incentive to rewet the land, as wetland restoration is the only thing that approximately eliminates emissions.

The Expert Group's models all only include a low tax on emissions from carbon-rich agricultural land. Instead of a high tax, a subsidy is given for wetland restoration in combination with a low tax, which must be revisited in 2027 with the aim of increasing the tax if there is no prospect of rewetting a total of 37,000/70,000 hectares of carbon-rich agricultural land in 2030 and 2032, respectively, including previous projects. The prospect of a higher tax in the future is more credible if it is backed up now by a decision to introduce a tax on carbon-rich agricultural land from 2030. Once a tax has been decided on and implemented, it is administratively simpler to raise it in order to reach the raising the rate, if necessary, to reach the target of the set-aside. The subsidy for wetland restoration combined with the tax is expected to provide CO_2-eq reductions in 2030 of 0.3 m tonnes and reductions in 2032 of 1.0 m tonnes in 2032.

In addition, all the Expert Group's models include a tax on greenhouse gas emissions from the use of F-gases of DKK 750 per tonne of CO_2-eq, corresponding to the tax rate for companies outside EU ETS. It is expected to contribute 0.1 m tonnes of CO_2-eq reductions by 2030.

Not all emissions are included in the tax base

Certain emissions from agricultural field operations are not covered by the Expert Group's models. Among these are some insignificant emission sources where the reduction effect is not deemed to be commensurate with the administrative burden of taxation. A more significant source is nitrous oxide emissions from crop residues, but as these emissions are part of a close and complex interaction with nitrogen regulation, which is currently under review, they are not included in the models presented here. The Expert Group calls for the regulation of these emissions to be included in a new model for nitrogen regulation. Another source of emissions in crop production is indirect nitrous oxide emissions from applied fertiliser, which occur via ammonia evaporation and subsequent deposition of nitrogen, as well as nitrogen leaching and runoff from the field. These emissions are calculated at a national level by combining a number of factors. The Expert Group does not include these indirect emissions in the tax base, as it is difficult to attribute them to the individual farm in a way that ensures a direct link between the individual farmer's activity and the national inventory. Overall, approx. 15 per cent of emissions from agriculture and forestry are not covered by the Expert Group's models for the reasons mentioned above. However, on a national level, the farmer's adjustment to the fertiliser tax on direct nitrous oxide emissions will contribute to lowering indirect emissions. This effect is included in the Expert Group's calculation of the total greenhouse gas reductions.

Key figures for the models

Key figures for the Expert Group's models are shown in *Table 1*. The Expert Group assumes a phase-in from 2027 based on the premise that a political agreement that follows up on the models presented to achieve the climate targets is reached quickly.

The "shadow price" in the penultimate column of *Table 1* indicates the average socio-economic cost per tonne of CO_2-eq reduction. The shadow price measures the loss of economic welfare due to the cost increase of the regulation minus the most important environmental spin-off benefits (besides the benefit of the CO_2-eq reduction itself). Specifically, the shadow price is reduced by the health benefits of reduced ammonia evaporation, the recreational value of increased forest areas, and the reduction in the cost of meeting EU requirements for water quality resulting from lower nitrogen leaching. The rewetting of carbon-rich agricultural land can also contribute to more and better nature on land and increase the diversity of plant and animal species on the land. The benefits of this are difficult to calculate and are not recognised in the shadow prices, which therefore underestimate the environmental benefits of climate regulation of agriculture.

In model 2, the nominal rate for the livestock tax is maintained at DKK 750 per tonne of CO_2-eq, but a base deduction of 50 per cent of the tax payment per animal is given, thereby lowering the effective tax rate to DKK 375 per tonne of CO_2-eq. On the margin, however, the farmer must pay DKK 750 per tonne of CO_2-eq for increased emissions per animal. Still, the farmer is simultaneously rewarded with a tax saving of DKK 750 per tonne of CO_2-eq when introducing emissions reducing measures such as feed additives. This maintains a high incentive to switch to more climate-friendly operations, but the base deduction lowers the total tax burden. In model 3, the nominal rate for the livestock tax and thus the incentive to reduce emissions per animal is DKK 250 per tonne of CO_2-eq, but the base deduction of 50 per cent reduces the average effective tax rate to DKK 125 per tonne of CO_2-eq.

In all three tax models, fertiliser applied to fields is subject to a tax of DKK 750 per tonne of CO_2-eq to maintain a high incentive to reduce fertiliser application at the margin, but in models 2a and 3a the average effective tax rate is halved via an area-based base deduction that is allocated per hectare on the same basis as the hectare subsidy in the EU's common agricultural policy. As an alternative to a fertiliser tax, models 2b and 3b provide a subsidy of DKK 750 per tonne of CO_2-eq for reduced fertiliser usage if the farmer reduces the fertiliser usage below the applicable norm in the nitrogen regulation. The subsidy is financed by a reduction of the hectare subsidy for all farmers, regardless of whether they reduce the fertiliser application or not. In this way, part of the agricultural subsidy is converted from passive support to supporting the climate transition of the agricultural sector. The restructuring is thus revenue-neutral for the state. Compared to the fertiliser tax with a base deduction, the fertiliser reduction subsidy provides slightly fewer CO_2-eq reductions at a higher shadow price. On the other hand, the subsidy model results in a slightly smaller decrease in agricultural production than the tax model.

In models 1 and 2, the marginal rate for the livestock tax is sufficiently high to ensure that it is favourable for farms to introduce technical measures such as feed additives and covering of slurry storage facilities, as these measures are expected to be included in the emissions inventory in 2030. In model 3, the tax rate is too low to ensure that farmers adopt these measures. To ensure the necessary CO_2-eq reductions, it is therefore a requirement that farms utilise these measures.

Models 2 and 3 include a public subsidy fund every year until 2030 to support the expansion of the use of biochar produced by pyrolysis. Biochar stored in agricultural soil is a way for agriculture to achieve negative emissions through carbon sequestration that can compensate for the inevitable emissions from other agricultural sources. This is necessary to realise long-term climate goals. The purpose of the subsidy is to promote the further development and cost reduction of pyrolysis technology so that in the long term it can compete with other technologies on market terms, supported by effective climate regulation. To ensure that the support has a climate effect, it is only paid out once it has been documented that the biochar has been stored in the ground. In model 3, biochar produced by pyrolysis contributes CO_2-eq reductions of 0.8 m tonnes of CO_2-eq in 2030. It is uncertain whether such an upscaling of the pyrolysis capacity can be achieved before 2030, and the development in the area must, therefore, be continuously monitored to assess whether additional measures will be needed in model 3 to ensure that the 70 per cent target is met. Environmental approval for the storage of biochar in agricultural land is pending, which also contributes to uncertainty about meeting the 70 per cent target, especially in model 3.

The immediate burden on business in the fifth column of *Table 1* shows the burden placed on agriculture in a hypothetical situation with unchanged behaviour and unchanged market prices and prices of inputs in production. In model 1, the immediate burden on the agricultural sector is estimated to be around DKK 5.9 bn. When a base deduction is introduced in model 2, the burden is reduced to DKK 3.1 bn and DKK 2.5 bn in models 2a and 2b, respectively. However, fewer CO_2-eq reductions are achieved. Models 3a and 3b imply an even lower immediate burden of DKK 1.9 bn and DKK 1.3 bn, respectively. With a lower immediate burden of business comes a decline in production. This requires additional subsidies for technological reductions, which increases the socio-economic cost, the shadow price. Furthermore, the uncertainty associated with the reductions increases as a larger contribution is assumed from technologies that are not market-ready today.

The burden on the agricultural sector will be significantly less than the above-mentioned amounts once farms and agricultural sales prices and input prices have adjusted to the tax/subsidy. This is also true when you factor in the value of the production lost when the least profitable farms are closed down as a result of the regulation.

In model 1, the state is estimated to achieve an annual net revenue of approx. DKK 1.2 bn after the sector has adapted to the tax. The proceeds can be returned to the industry in the form of a subsidy scheme for testing and transition to new climate-friendly agricultural technologies and/or for support for transition to greener methods of production in the form of state compensation for the demolition of livestock buildings etc. in animal farms that permanently convert to crop production. In model 2, there is a limited loss of state revenue of just over DKK 0.5 bn annually, which will require financing, while model 3 involves a somewhat larger annual financing requirement of just over DKK 2 bn.

Table 1. The Expert Group's models

	Carbon-rich agricultural land				**Afforestation**		**F-gases**	
Common elements	Increase in the funds for set-aside and wetland restoration costs of DKK 9.4 bn Introduction of a tax of DKK 10 per tonne of CO_2-eq (increases with low set-aside)				Subsidy of DKK 92,000 per hectare		Tax of DKK 750 per tonne of CO_2-eq	
	Regulation			**CO_2-eq reduction [1]**	**Costs and revenues**		**Shadow price**	**Land value decline**
	Livestock	Fertiliser	Biochar by pyrolysis	2030	Immediate burden	Revenue after behavioural response and subsidy	Avg. incl. side effects	Incl. afforestation
				m tonnes	*DKK bn*		*DKK per tonne of CO_2-eq*	*Per cent*
Model 1 (Effective tax rate of DKK 750 per tonne of CO_2-eq)	Tax of DKK 750 per tonne of CO_2-eq	Tax of DKK 750 per tonne of CO_2-eq		3.2	5.9	1.2	150	8.8

Model 2a (Effective tax rate of DKK 375 per tonne of CO_2-eq)	DKK 750 per tonne and a base deduction of 50 per cent.	DKK 750 per tonne and a base deduction of 50 per cent.	DKK 225 m annually public funds	2.8	3.1	-0.5	250	-4.1
Model 2b (Restructuring of direct agricultural subsidies)	DKK 750 per tonne and a base deduction of 50 per cent.	Subsidy of DKK 750 per reduced tonne of CO_2-eq financed by restructuring direct agricultural subsidies	DKK 225 m annually public funds	2.6	2.5	-0.7	325	-2.8
Model 3a (Effective tax rate of DKK 125 per tonne of CO_2-eq)	DKK 250 per tonne and a base deduction of 50 per cent.	DKK 750 per tonne and a base deduction of 50 per cent.	DKK 1.150 m annually public funds	2.6	1.9	-2.0	475	-7.2
Model 3b (Restructuring of direct agricultural subsidies)	DKK 250 per tonne and a base deduction of 50 per cent.	Subsidy of DKK 750 per reduced tonne of CO_2-eq financed by restructuring direct agricultural subsidies	Up to DKK 1,150 M annually public funds	2.4	1.3	-2.1	575	-6.0

Source: 1. Including CO_2-eq reduction in 2030 of 0.3 m tonnes from wetland restoration of carbon-rich agricultural land, 0.1 m tonnes from afforestation and 0.1 m tonnes with higher tax on F-gases.

The risk of bankruptcies in agriculture

The Expert Group has assessed the risk of bankruptcies in agriculture as a result of the models presented. The bankruptcy risk is highly dependent on the assessed effects on agricultural land values and the value of the industry's buildings and machinery. In the absence of afforestation subsidies, the Expert Group's models are estimated to result in a significant decline in land values, especially in model 1, but the afforestation subsidy helps to keep land values up. In models 2 and 3, the effect of afforestation is sufficient to protect against a general decline in land values, although the geographical effects on land values will depend on the specific local opportunities for afforestation.

Other agricultural capital values are expected to decrease in all models, especially in model 1, but somewhat less in models 2 and 3. The report's calculations indicate that the immediate burden on the agricultural sector due to model 1 will increase the average bankruptcy risk across full-time farmers by 15 percentage points. In contrast, cattle farms will experience an increase in bankruptcy risk of 25 percentage points. In model 2, the increase in the risk of bankruptcy among all farms and cattle farms is estimated to be limited to 4-5 percentage points and 10-11 percentage points, respectively, whereas the impact of model 3 is so minor that no significant increase in the risk of bankruptcy is expected. When taking the possibilities for farms to reduce their costs by adapting to the new regulation and the expected increase in agricultural sales prices into account, the increase in the risk of bankruptcy will be smaller than the figures mentioned. Furthermore, not all farms at risk of bankruptcy will actually go bankrupt.

Effects on food prices, distribution and employment

As mentioned, the burden on the agricultural industry is reduced by the fact that a part of the industry's cost increase can be expected to be passed on in the settlement prices for deliveries to dairies and slaughterhouses, which will lead to a rise in consumer prices for processed food. However, even in model 1, consumer prices on Danish dairy and meat products are only expected to increase by just under 4 per cent. After taking into account adjustments in other prices, wages and transfer incomes, the estimated effects on inequality in the distribution of real disposable income is unaffected measured by the Gini coefficient.

The introduction of a CO_2-eq tax on agriculture leads to a permanent decline in employment in agriculture and the food industry of almost 8,000 full-time equivalents in model 1, and about half and a quarter of this in model 2 and model 3. Total employment falls by a similar amount in the short term. However, over time, total employment in the economy will rise back towards the starting point as the freed-up labour moves to other industries.

The Expert Group has also analysed how the presented models affect the economy in different parts of the country. This was done by calculating how much the loss of gross value added (GVA) in agriculture represents of the total GVA in 11 different parts of the country. On average for the whole country, agriculture's loss of GVA amounts to 0.3 per cent of Denmark's total GVA in model 1, and somewhat less in models 2 and 3. In West Jutland, where the economic importance of agriculture is greatest, the industry's loss of GVA amounts to 1.1 per cent of the region's total GVA in model 1 and about half of this in model 2. The limited effect reflects the fact that agriculture only makes up a small proportion of the economy even in the parts of the country where the profession is most widespread. The figures do not include the impact of production in dairies and slaughterhouses. If these ancillary industries are included, the regional effects may be slightly larger. It should be emphasised that these figures do not indicate the net effect on the regions' GVA, as some of the resources released from agriculture will be used and thus create added value elsewhere in the same region in industries with less CO_2-eq-intensive production.

Denmark's contribution to the global food supply

The Expert Group has also analysed whether the presented models risk causing a significant decrease in Denmark's contribution to the global food supply, measured by the total Danish production of calories for human consumption. The analysis is inevitably subject to great uncertainty, but indicates that in the Expert Group's models, it will be possible to maintain a largely unchanged calorie production in Danish agriculture. This is because the decline in animal production and the associated land use for livestock feed production will free up land that can potentially be used to produce plant-based food for human consumption.

Uncertainty factors

The calculations in the report are subject to considerable uncertainty, partially due to no other countries having experience with similar climate regulation of agriculture. The Expert Group has therefore made a number of calculations of the sensitivity of the reported results to changes in the assumptions about the size of key parameters about which there is uncertainty. Among the key parameters are the price elasticities of agricultural exports, which indicate how much foreign demand for Danish agricultural goods falls when their prices rise. With a higher price elasticity, it will be more difficult to pass on a CO_2-eq tax in the prices of Danish agricultural products, and the tax will therefore have a greater impact on the industry's earnings and production. Conversely, a lower price elasticity will reduce the decline in earnings and output.

However, the sensitivity analyses carried out do not cover all dimensions of the uncertainty surrounding the report's calculations, partly because there is uncertainty about how well the Expert Group's modelling reflects reality. In light of the lack of experience with introducing a general CO_2-eq tax on agricultural emissions, the Expert Group calls for close and continuous monitoring of whether the development in agricultural emissions and economic conditions correspond to the expected effects of the CO_2-eq regulation decided politically. If this is not the case, the Expert Group suggests reassessing the overall taxation of greenhouse gas emissions — not just agriculture — to ensure that the uniform tax structure across sectors is maintained.

A climate tax on end consumption

After the formation of the current government, the Expert Group's terms of reference were expanded to include a request to analyse the pros and cons of imposing a CO_2-eq tax on end consumption. Such a consumption tax would be imposed at the retail level on the sale of processed foods to the final consumer, regardless of whether the product is produced in Denmark or imported from abroad. Food for export, on the other hand, should not be included in the tax base, as the purpose is only to tax emissions from domestic consumption. The consumption tax rate should ideally reflect the total amount of greenhouse gases emitted in the production and transportation of the product throughout the value chain until the product reaches the final Danish consumer.

In the Danish debate, a climate tax on the end consumption of food has been put forward as a possible alternative or supplement to a tax on greenhouse gas emissions from Danish agricultural production. One of the advantages of a climate tax at the consumption stage is that imported and domestically produced goods are taxed equally, thereby avoiding a deterioration in the competitiveness of Danish agriculture and the resulting risk of greenhouse gas leakage.

Due to this, the Expert Group has analysed the effects of imposing a tax on Danish consumption of particularly climate-impacting foods, which, in the report's calculations, are limited to beef, pork, and dairy products. For calculation purposes, it is assumed that the three product groups are subject to three different tax rates corresponding to the estimated total global emissions from the consumption of beef, pork and dairy products delivered from Danish slaughterhouses and dairies, including emissions from the import of raw materials and semi-finished products for use in Danish food production.

From a climate perspective, different taxes should be imposed on imported and comparable domestically produced food products if there is a difference in emissions per unit produced abroad and in Denmark, but the trade policy rules in the EU and the World Trade Organisation (WTO) require that the same tax is imposed on imported and comparable domestically produced goods. The Expert Group's calculations therefore assume that imported food products are subject to a tax that reflects the estimated global emissions from Danish production of comparable food products.

The Expert Group has assumed that Denmark is obligated to the EU and by the Danish Climate Act to reduce greenhouse gas emissions from Danish territory, including emissions from Danish agricultural production. On this basis, the Expert Group has investigated the extent to which a CO_2-eq tax at the consumption stage can replace a tax at the production stage as a means of achieving a given reduction in greenhouse gas emissions from Danish territory. Specifically, the Expert Group has compared the effects of a consumption tax of DKK 750 per tonne of CO_2-eq on the above-mentioned particularly climate-impacting foods with the effects of a CO_2-eq tax of DKK 750 per tonne in the production stage. For the sake of comparability, the tax at the production stage does not include emissions from Danish carbon-rich agricultural land, as it is hardly accurate to assume that imported food products give rise to similar emissions from foreign carbon-rich agricultural land. The basis for the analysed tax on domestic agricultural production is thus smaller than the tax base in the Expert Group's model 1.

Nevertheless, the base for the tax in the production stage is significantly broader than the base for the consumption tax. This is partly because the consumption tax only covers part of the total domestic food consumption, but even if the consumption tax was extended to cover all food consumption, the tax in the production stage would still have a significantly larger base. This is because Danish food production is significantly larger than Danish food consumption, as Denmark exports a large share of the food it produces. These factors help to explain why, according to the Expert Group's calculations, the introduction of a consumption tax of DKK 750 per tonne of CO_2-eq on particularly climate-impacting foods would only enable a reduction in the production tax from DKK 750 to around DKK 700 per tonne of CO_2-eq.

A further explanation is that food consumption and the associated greenhouse gas emissions are relatively insensitive to price increases. In contrast, international competition on the world market means that agricultural exports and associated emissions are significantly more sensitive to price increases due to a climate tax. Last but not least, a climate tax at the production level gives the individual farm a direct incentive to reduce emissions, which is not the case with a consumption tax, which must necessarily be based on the average emissions from the entire agricultural sector, over which the individual farmer has little influence.

As a result of these factors, the shadow price of domestic CO_2-eq reductions is many times higher with a consumption tax than with a production tax, and the shadow price of reducing *global* emissions is also much higher with the consumption tax, as it is estimated to provide only a very limited reduction of emissions abroad. In addition, the introduction of a differentiated climate tax on food is estimated to entail very large administrative challenges for both authorities and industry, similar to the practical problems that led to the abolition of the previous fat tax. For this reason, a climate tax on end consumption is not included in the Expert Group's models.

The fundamental trade-off: Cost-effectiveness versus preservation of the business structure

In summary, the Expert Group's models 1-3 for a production tax in the agricultural production chain can be seen as a mirror image of the models in the first interim report on a CO_2 tax on industry etc. In the first interim report, a lower tax level was followed by higher socio-economic costs (higher shadow prices) and required a larger reduction contribution from technology. The Expert Group's models in this report, which focus on agriculture, also limit the impact on the existing business structure by reducing the tax level and increasing the share of CO_2-eq reductions from technological change. Models that increase the share of technological reductions thus play a significant role in the Expert Group's consideration of deviating from the strict cost-effectiveness requirement. The cost of reducing the tax level and increasing the technological reductions relative to reductions achieved by production cuts is fewer CO_2-eq reductions and higher socio-economic costs, as well as an increased need for financing. The increase in socio-economic costs and financing needs can be interpreted as *the price* of reducing the burden on the agricultural sector and the risk of carbon leakage from agriculture.

The Starting Point for a Green Tax Reform

1

1. The Starting Point for a Green Tax Reform

After concluding *the Agreement on Green Tax Reform* of December 2020, the parties to the agreement agreed in February 2021 on a terms of reference for the Expert Group's work*, see Appendix 7.1*. The terms of reference state that the Expert Group will:

- Prepare models for uniform CO_2-eq regulation, including the design of a more uniform CO_2-eq tax.[1]
- Develop different scenarios that contribute significantly to the 70 per cent target, taking into account the guiding principles of the Danish Climate Act. The starting point for the scenarios must be that they deliver the most cost-effective solution. If there is a deviation from the socioeconomically least costly solution, reasons must be given.

The terms of reference state that the work of the Expert Group will be divided into two reports, which together will form a comprehensive analysis. The first report from 6 February 2022 presented proposals for restructuring energy taxes to a more direct tax on CO_2 emissions and expanding the tax base to well-defined areas that were previously exempt from tax. The first interim report focused on a tax on emissions, carbon removal from industry, heat and electricity production and non-road transport. The report also proposed a restructuring of energy taxes on petrol, diesel and space heating into a CO_2 tax.

With this second and final interim report, the Expert Group describes models for a more uniform CO_2-eq regulation across the entire economy, including road transport and non-energy related emissions from agriculture, taking into account the guiding principles of the Danish Climate Act.

In addition to the Expert Group's original terms of reference, the basis for the current government states that "*The climate tax must ensure implementation of the development track and fulfilment of the binding reduction target for the agriculture and forestry sector of 55-65 per cent in 2030 compared to 1990. The government will ask the expert committee to present different scenarios for achieving this goal in line with the recommendations the committee presented in connection with the CO_2-eq*

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[1] The term 'CO_2-eq' stands for "CO_2 equivalents". This covers the fact that agriculture's non-energy-related emissions consist mainly of the greenhouse gases nitrous oxide (N_20) and methane (CH_4), which for the sake of comparability are converted to CO_2 equivalents, i.e. to the CO_2 emission that has the same climate impact as the emission of the greenhouse gas in question.

tax on industry, including consideration of counteracting the relocation of production, including international experience and the possibility of applying a CO_2-eq tax on end consumption as a possible instrument".

The second report will also assess the advantages and disadvantages of a regulatory solution for the agricultural sector, a subsidy model for EU agricultural support and a CO_2-eq tax for this sector or a combination of these, as well as possible measures for cost-effective regulation of agriculture that address CO_2-eq emissions and other externalities, including e.g. environment and health.

Contributions to meeting the reduction targets of the Danish Climate Act can take the form of CO_2 emission reductions and negative CO_2 emissions, for example, by capturing and storing CO_2 from biomass and biogas, as negative emissions are counted towards the 70 per cent target on an equal footing with CO_2 reductions. In order to achieve cost-effective regulation, the incentive for greenhouse gas reduction must, to the greatest degree possible, be uniform across the entire economy. This could be ensured, for example, by providing a subsidy – a so-called negative tax – for negative CO_2 emissions at a rate equivalent to the CO_2 tax rate.

In addition, the terms of reference state that, in addition to a uniform CO_2, appropriate compensation and feed-back mechanisms should be identified to support the guiding principles of the Danish Climate Act. Thus, the report analyses the consequences of a number of different measures that can reduce the impact on agriculture, *see Section 2.10*. *Chapter 2* also describes the effects of a CO_2-eq tax on employment and income distribution in the areas covered by this report.

Finally, the additional terms of reference state that the Expert Group must, as part of its final report, *"analyse the advantages and disadvantages of imposing a CO_2-eq tax on end consumption"*. This is described in more detail in *Section 4*.

1.1 The Expert Group's Interpretation of the Terms of Reference and the Guiding Principles of the Danish Climate Act

In accordance with the terms of reference, the Expert Group's analyses are based on the guiding principles of the Danish Climate Act.

The requirement for *cost-effectiveness* in climate action is at the centre of the Danish Climate Act and the terms of reference and is, therefore, the starting point for the Expert Group's work. Cost-effectiveness means that greenhouse gas reductions are achieved at the lowest possible socio-economic cost, i.e. with the lowest possible loss of economic welfare for citizens in general in the form of e.g. lower real wages and transition costs.

A CO_2-eq tax gives individual businesses (including farms) and households a direct incentive to reduce their emissions in the way that is cheapest for them. A key advantage of using the tax instrument is that it exploits the knowledge of companies and households themselves on how best and cheapest to reduce emissions. This mobilises valuable knowledge about reduction opportunities that authorities often do not have. However, to ensure full cost-effectiveness in connection with a CO_2-eq tax on agriculture, it is important that the authorities provide knowledge that enables tax reductions when agricultural enterprises introduce new practices that reduce their greenhouse gas emissions.

The Danish Climate Act's 70 per cent target relates to CO_2-eq emissions from Danish territory. Thus, it is irrelevant whether Danish or foreign companies or consumers are behind the activities that cause the emissions. It only matters whether the emissions take place outside or within Denmark's borders. A fully cost-effective CO_2-eq tax to reduce domestic emissions requires that the tax is the same across all activities in all domestic sectors and that negative domestic emissions are subsidised at a rate equal to the tax rate. Such a uniform CO_2-eq tax ensures the same incentive to lower emissions everywhere in the domestic economy, thereby concentrating reduction efforts in areas where they are cheapest.

However, the Danish Climate Act and the terms of reference also mention other important considerations that are not necessarily compatible with the requirement for full cost-effectiveness, including ensuring *cohesion and social balance* and limiting *carbon leakage*, where production and associated emissions are moved abroad. Both of these considerations can be challenged by the *paradigm shifts in business* that a uniform CO_2-eq tax must be expected to bring about.

The Danish Climate Act and the terms of reference include principles for social balance, including that the costs of meeting the climate target must not be unevenly distributed across income groups. The report's analyses show that none of the tax models described increase inequality in income distribution.

The Expert Group's analyses show that the introduction of a uniform CO_2-eq tax to meet Denmark's climate commitments in the EU and the national climate targets will lead to a decline in domestic Danish agricultural production.

Freed-up labour and capital will eventually enter other parts of the Danish economy. The adjustment costs of these paradigm shifts in business will be small relative to Denmark's overall economy, but they may be noticeable in some local areas. The analyses thus reveal an inevitable dilemma between the objective of for cost efficiency and the preservation of existing business structures. Against this background, in Chapter 2, the Expert Group has chosen to present three overall models, as well as different versions of these, for climate regulation of agriculture that emphasise these considerations differently in order to illustrate the political trade-offs that must necessarily be made.

According to the Danish Climate Act, Denmark's climate action must be compatible with *sound public finances* and the terms of reference require the Expert Group to present alternative scenarios, at least one of which involves no overall increase in taxes and duties.

Chapter 2 contains a scenario where the revenue from the CO_2-eq tax is used for compensatory subsidies/compensation. Finally, Chapter 2 includes a scenario where the compensatory measures require additional financing beyond the tax revenue.

The rest of this chapter provides an overview of Denmark's greenhouse gas emissions as well as one of Denmark's national climate targets and international climate commitments.

1.2 Denmark's Greenhouse Gas Emissions

In 2021, Denmark's total greenhouse gas emissions were 46.2 m tonnes of CO_2-eq, *see Climate Status and Outlook 2023*. With the climate policy measures adopted so far and the partial correction for the new map of carbon-rich agricultural land, Denmark's total greenhouse gas emissions are estimated to be approx. 27 m tonnes of CO_2-eq in 2030.

This report mainly deals with non-energy related emissions from agriculture and forestry etc. *Climate Status and Outlook 2023* are the basis for the calculations in the report. With *Climate Status and Outlook 2024,* which will be published in April 2024, the inventory and projection of emissions will be updated.

In this report, all greenhouse gas emissions are converted to CO_2-eq, *see Box 1.1*.

Box 1.1

Greenhouse gases

Greenhouse gases are a term for gases that contribute to the greenhouse effect. When the concentration of greenhouse gases in the atmosphere increases, it causes changes in the greenhouse effect that can cause the Earth's temperatures to rise and change the Earth's climate. Greenhouse gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and the so-called F-gases (e.g. refrigerants). The gases have different greenhouse effects, but are converted to CO_2 equivalents (abbreviated CO_2-eq) based on the warming potential of each individual gas (Global Warming Potential, abbreviated GWP) in a hundred-year perspective in relation to CO_2. GWP values are updated on an ongoing basis as new knowledge in the field becomes available. To avoid inconsistencies in the time series of greenhouse gas emissions, IPCC guidelines require the recalculation of the annual greenhouse gas emissions inventories back to 1990 when the GWP values are updated.

All countries that are part of the Paris Agreement have committed to use GWP values over a 100-year period based on the IPCC's Fifth Assessment Report (AR5) from 2024 at the latest (i.e. in the 2022 inventory). This allows emissions inventories to be compared across countries, increasing the ability to check whether each country's climate accounts are credible and well-documented. Thus, using other GWP values for reporting national emissions inventories would be inconsistent with the reporting requirements of the Paris Agreement.

The Ministry of Climate, Energy and Utilities has since the Climate Status and Outlook 2021 used AR5, which reduces data breaks in the projection and between the inventory and the projection.

In AR5, methane (CH_4) is calculated with a GWP value of 28 and nitrous oxide (N_2O) of 265, which means that one tonne of methane contributes 28 times more and one tonne of nitrous oxide 265 times more to the greenhouse effect than one tonne of carbon dioxide (CO_2).

In connection with the IPCC's sixth report (AR6), updated GWP values were published. It is not yet planned when the inventories to the UN will be updated for this. It should be noted that the US *Environmental Protection Agency* has chosen to use AR6 for scientific reports, but continues to use AR5 for reporting to the UN.

	UN Intergovernmental Panel on Climate Change assessment reports		
Greenhouse gases			
	AR4	AR5	AR6
CO_2	1	1	1
CH_4 (fossil)	25	28	29.5
CH_4 (non-fossil)	25	28	27.2

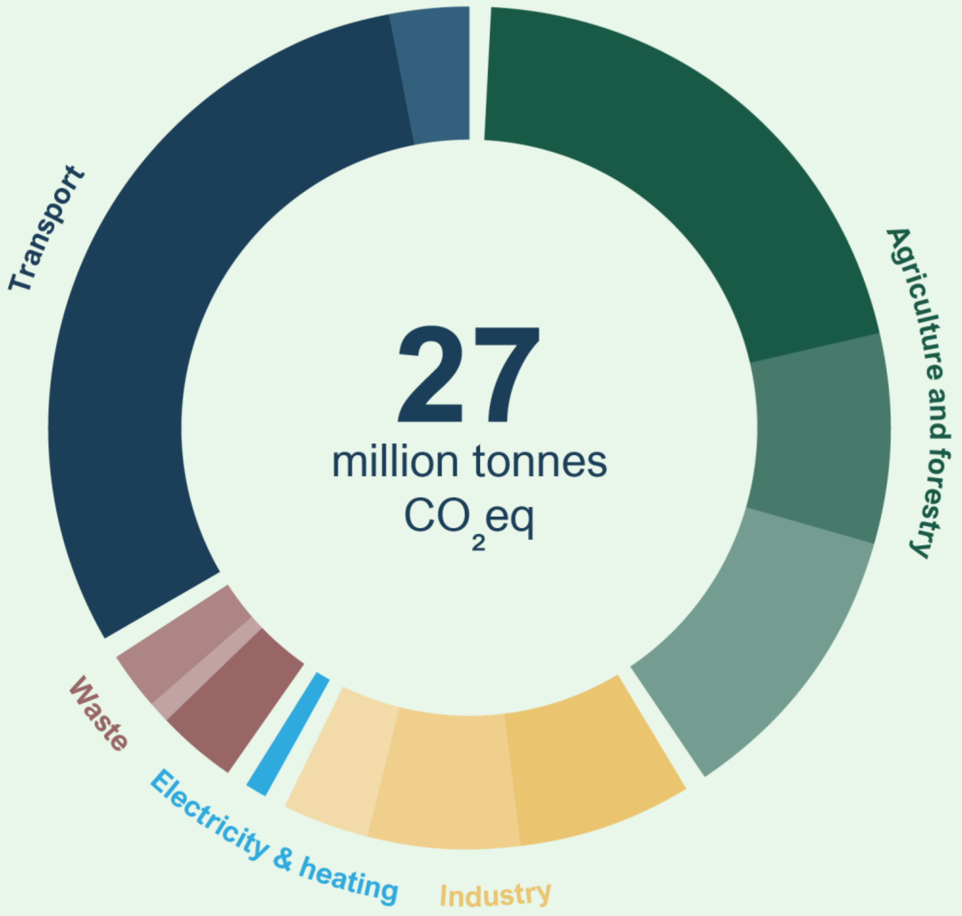
N_2O	298	265	273

Non-energy-related emissions from the agriculture and forestry sector are estimated to be 12.4 m tonnes of CO_2-eq in 2030, corresponding to approx. 46 per cent of Denmark's total emissions in 2030. Estimated emissions of 9.6 m tonnes of CO_2-eq from road transport and 1.9 m tonnes of CO_2-eq from waste and F-gases. In addition, emissions of 6.2 m tonnes of CO_2-eq are estimated from industry, non-road transport, electricity and heat.

Greenhouse gas emissions from agriculture and forestry are a result of agricultural and forestry operations, including natural biological processes such as methane from livestock digestion processes, nitrous oxide from fertiliser application, and the decomposition of carbon and nutrients in the soil. The emissions will typically vary depending on natural conditions such as temperature, rainfall and soil conditions.

Existing environmental regulation contributes to lowering non-energy-related greenhouse gas emissions from agriculture and forestry. Therefore, it is relevant to elucidate the interaction between a future regulation of greenhouse gas emissions and the existing environmental regulation. The main features of the current environmental regulation of agriculture and forestry can be found in *Chapter 6*. In addition, the current regulation of fertilisers and field management is described in *Section 3.2*.

Denmark's Greenhouse Gas Emissions in 2030



Industry

●	Industry etc.	2,1
●	Refineries and gas	1,9
●	Other	1,0

Electricity & heating

●	Electricity and heating	0,3

Waste

●	Waste incineration	1,0
●	F-gases	0,2
●	Other	0,7

Transport

●	Road transport	9,6
●	Non-road transport	0,9

Agriculture and forestry

●	Animal production	6,5
●	Land use	2,3
●	Crop production	3,6

Not divided by sector

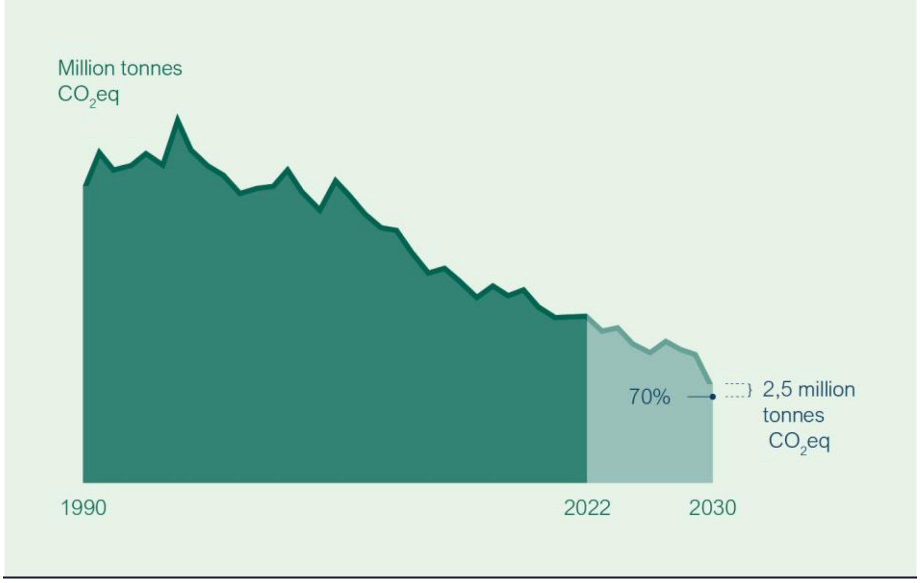
CCS	-3,2

In the government's *Climate Status and Outlook* 2023, it was estimated that new climate policy measures would be needed to ensure further greenhouse gas reductions of 5.4 m tonnes of CO_2-eq in 2030 to meet the 70 per cent target. Since the publication of *Climate Status and Outlook 2023*, the government has presented the implementation of the revised EU Emissions Trading System Directive, an agreement on green aviation and a proposal for an increase in the diesel tax, which together is estimated to reduce the shortfall to the 70 per cent target to 4.5 m tonnes of CO_2-eq in 2030. The reduction deficit in relation to reaching the 70 per cent target in 2030 has been further adjusted down by DKK 2 m tonnes of CO_2-eq as a result of the partial correction for the new map of carbon-rich agricultural land.

The starting point for the Expert Group's calculations is thus that the reduction deficit in relation to meeting the 70 per cent target in 2030 is reduced from 5.4 m to 2.5 m tonnes of CO_2-eq relative to the *Climate Status and Outlook 2023, see Figure 1.1*.

In addition to the 70 per cent target, the government has set a target for Denmark to be climate neutral by 2045 and for net emissions to be reduced by 110 per cent by 2050 compared to 1990.

Figure 1.1 - Total net emissions relative to reduction targets



Source: Climate Status and Outlook 2023

Denmark's total reduction deficit under the EU's Effort Sharing Regulation is estimated to be approx. 11.5 m tonnes of CO_2-eq over the period 2021-2030, when the government's proposal for a diesel tax and implementation of the revised EU Emissions Trading System Directive are included.

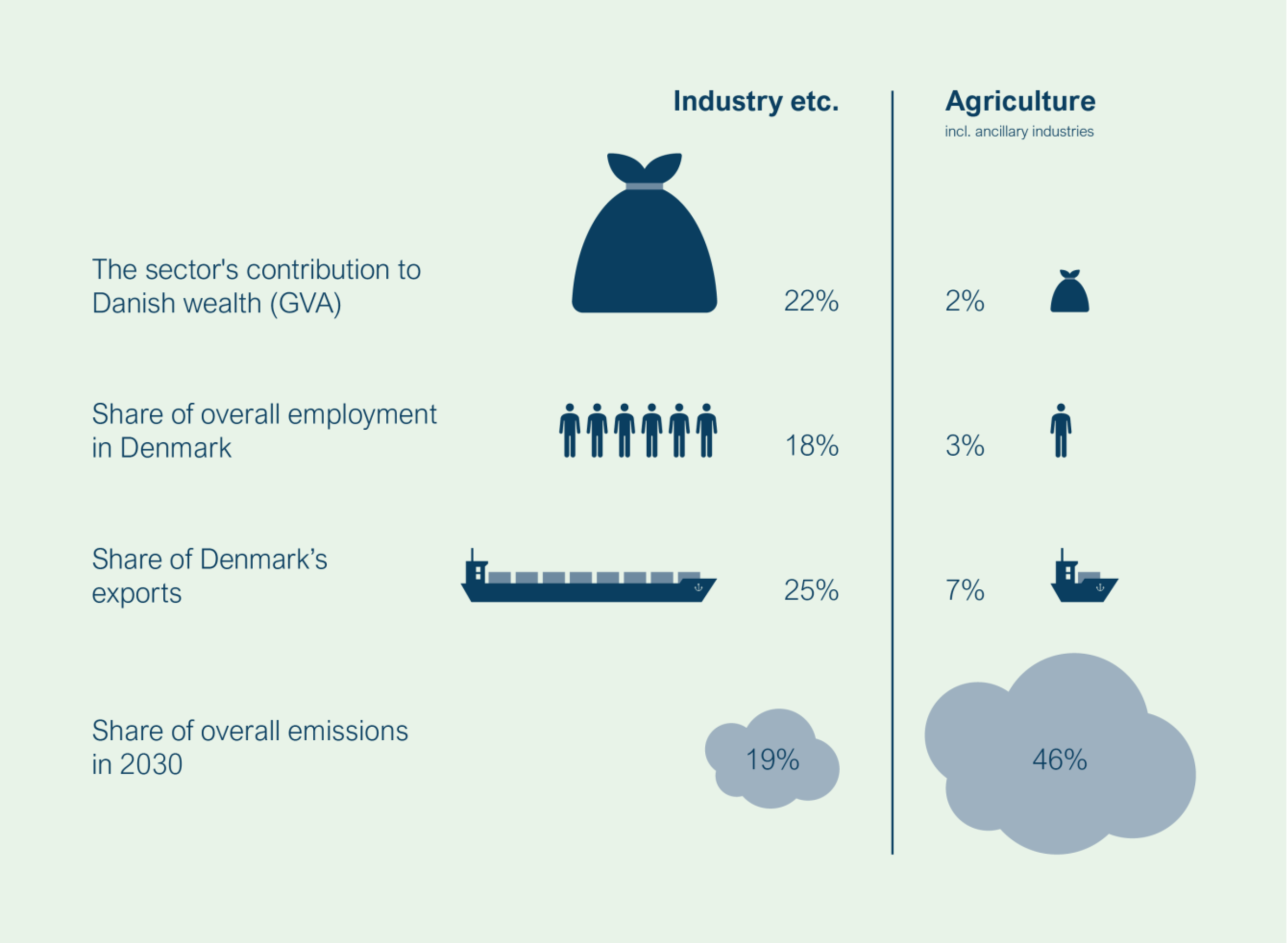
Denmark's reduction deficit in emissions and removals from agricultural land use and the forest sector (LULUCF[2] commitment) is estimated to be around 7.0 m tonnes of CO_2-eq in the period 2026-2029 and around 1.1 m tonnes CO_2-eq in 2030, taking into account the downward adjustment due to the updated map of carbon-rich agricultural land.

[2] Land Use, Land-Use Change and Forestry

Agriculture accounts for a large share of Danish greenhouse gas emissions in 2030 relative to the sector's share of the Danish economy, *see Figure 1.2*. Agriculture and its ancillary industry contribute approx. 2 per cent to Danish prosperity (measured by gross value added), while the rest of the industry contributes approx. 22 per cent. Similarly, agriculture and its related industries only account for 3 per cent of Danish employment, while the rest of industry accounts for 18 per cent of employment. However, by 2030, agricultural emissions will account for 46 per cent of total emissions, while industry accounts for only 19 per cent.

The high emissions for agriculture should also be seen in the context that other CO_2-eq-intensive industries have already been subject to regulation with the aim of reducing their emissions by 2030. This applies in particular to industry, which was addressed in the first interim report, as well as road transport, which has been regulated through several political agreements, especially the *Agreement on the Green Transition of Road Transport* from December 2020.

Figure 1.2. Overview of economic key figures for industry and agriculture



Note: Agriculture is incl. secondary industry (slaughterhouses and dairies), while industry is excl. agriculture and its ancillary industry. For agricultural emissions, the starting point is the non-energy-related emissions from agriculture and forestry.

Source: The Expert Group's calculations based on data from Statistics Denmark and *Climate Status and Outlook 2023*, including partial corrections for the implementation of the revised EU Emissions Trading System Directive, the agreement on green aviation, the proposal to increase the diesel tax, and the new map of carbon-rich agricultural land.

1.2.1 Emissions from agriculture and forestry

Non-energy-related emissions from agriculture and forestry amounted to 11.8 m tonnes of CO_2-eq in 2021, corresponding to 27 per cent of Denmark's total emissions. The total non-energy-related emissions from the two sectors are estimated to be 12.4 m tonnes of CO_2-eq in 2030, including the partial correction for the new map of carbon-rich agricultural land, corresponding to 46 per cent of Denmark's total emissions in 2030.

In general, these emissions can be divided into three categories: emissions from animal production, emissions from crop production and emissions from land use (LULUCF), including afforestation. In 2030, animal production is expected to account for 52 per cent of the total emissions from the agriculture and forestry sector, *see Table 1.1*. Crop production is expected to account for almost 29 per cent. Emissions from land use, which mainly originate from drained carbon-rich agricultural land, are estimated to account for almost 19 per cent. The largest single emission sources are emissions from dairy cattle and from carbon-rich soil. It should be noted that removals and emissions from forests have a large influence on the sector's total emissions, but that net removals from forests in 2030, *see Table 1.1*, are estimated to be 0. The individual emission sources are summarised in *Appendix 7.3*.

This report considers emissions from the sectors totalling 10.6 m tonnes of CO_2-eq, *see Table 1.1*. This corresponds to approx. 85 per cent of all emissions from the agricultural and LULUCF sectors.

Table 1.1. Emission sources in agriculture and forestry

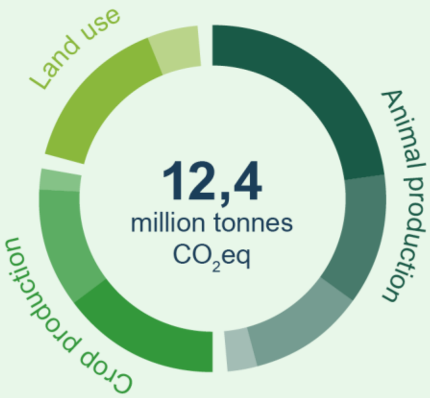
		m tonnes of CO_2-eq, 2030	Share of emissions from agriculture and forestry in 2030, per cent	Included in the Expert Group's models (✓)/indirectly included (*)
The agricultural sector	**Total livestock**	**6.5**	**52.3**	
	Dairy cows	3.1	24.7	✓
	Other cattle	1.5	11.7	✓
	Pigs	1.6	13.0	✓
	Poultry	0.0	0.2	✓
	Other livestock	0.2	1.7	✓
	Indirect emissions from livestock	0.1	0.7	✓
	Grazing	0.0	0.2	*
	Total crop production	**3.6**	**29.0**	
	Artificial and organic fertilisers	1.7	13.8	✓
	Agricultural lime	0.2	1.8	✓
	Urea	0.0	0.0	✓

	Indirect nitrous oxide emissions from fields	0.6	4.7	*
	Burning of fields	0.0	0.0	
	Mineralisation	0.0	0.3	
	Cultivation of carbon-rich agricultural land	0.2	1.7	✓
	Crop residues	0.9	7.2	
LULUCF sector	Biomass	0.2	1.9	
	Carbon pool in mineral soils	-0.3	-2.5	
	Total land use	**2.3**	**18.6**	
	Carbon pool in carbon-rich agricultural land	1.9	15.7	✓
	Forest	0.0	0.0	✓
	Harvested wood products	-0.2	-1.9	*
	Buildings	0.3	2.3	
	Wetlands	0.3	2.5	
Total emissions		**12.4**	**100**	
Emissions directly subject to regulation in the Expert Group's models		**10.6**	**85.1**	
Total emissions		**12.4**	**100**	
	- agricultural sector of this	10.2	81.9	
	- of which LULUCF sector	2.2	18.1	

Note: Other livestock includes pheasants, ducks, mink, sheep, goats, horses, deer, lambs and ostriches. 0.0 does not mean that there are no emissions. There are just less than two decimal places. The total does not add up due to rounding.

Source: Climate Status and Outlook 2023, incl. partial correction for the implementation of the revised EU Emissions Trading System Directive, agreement on green aviation, proposal for an increase in the diesel tax, and the new map of carbon-rich agricultural land.

The agriculture and forestry sector's emissions in 2030



Animal production
6,5 million
tonnes
CO_2eq

Dairy cattle
25%

Pigs
13%

Other cattle
12%

Other livestock etc.
3%

Crop production
3,6 million
tonnes
CO_2eq

Spreading of fertilizer and agricultural lime on fields
16%

Field management etc.
12%

Organic soils (Cultivation)
2%

Land use
2,3 million
tonnes
CO_2eq

Organic soils (Carbon pool)
16%

Other land uses
5%

Forestry etc.
-2%

Proposed Models for a CO_2-eq Tax

2

2. Proposed Models for a CO_2-eq Tax

The terms of reference for the Expert Group's final report set out a number of factors that the Expert Group must include in its modelling of CO_2-eq reduction, *see Appendix 7.1*.

The Expert Group must, among other things, "*prepare models for uniform CO_2-eq regulation, including the design of a more uniform CO_2-eq tax*". In addition, it is stated that the second interim report must "*highlight models for a more uniform CO_2-eq regulation of all covered emissions.*"

The wording of the terms of reference means that the current regulation of CO_2 from energy consumption must be expanded to include greenhouse gas emissions from livestock and field operations in agriculture. Regulation with a tax on agricultural greenhouse gas emissions will constitute a new and independent tax on non-energy-related agricultural emissions, *see Chapter 5*. There is no necessary correlation between the tax rate on these emissions and the rates on energy-related emissions. However, the consideration of uniform CO_2-eq regulation of all covered emissions means that the Expert Group's regulation models for agriculture are based on the existing tax levels and the existing differentiation of rates in industry, etc. The models for agriculture thus use tax rates corresponding to those decided in connection with the *Agreement on Green Tax Reform for Industry etc.*, i.e. DKK 750, 375 and 125 per tonne of CO_2-eq in 2030. In addition, the models are calibrated to meet the 70 per cent target in 2030, the EU's Effort Sharing Regulation and the LULUCF Regulation.

2.1. The Expert Group's Overarching Considerations

Consideration for socioeconomics
The damaging effect of CO_2-eq emissions is the same regardless of where the emissions occur, and thus a socio-economically cost-effective regulation would mean that all CO_2-eq emissions are taxed at the same rate. Targets such as the 70 per cent target or EU obligations are met at the lowest socio-economic cost by applying the same *national* tax rate to all CO_2-eq emissions.[3]

A uniform CO_2-eq tax across sectors of the economy provides the socio-economically cheapest CO_2-eq reductions, as all branches of production will have a uniform incentive to reduce CO_2-eq emissions up to the point where the cost of further reductions exceeds the tax. If a CO_2-eq tax with differentiated rates is introduced,

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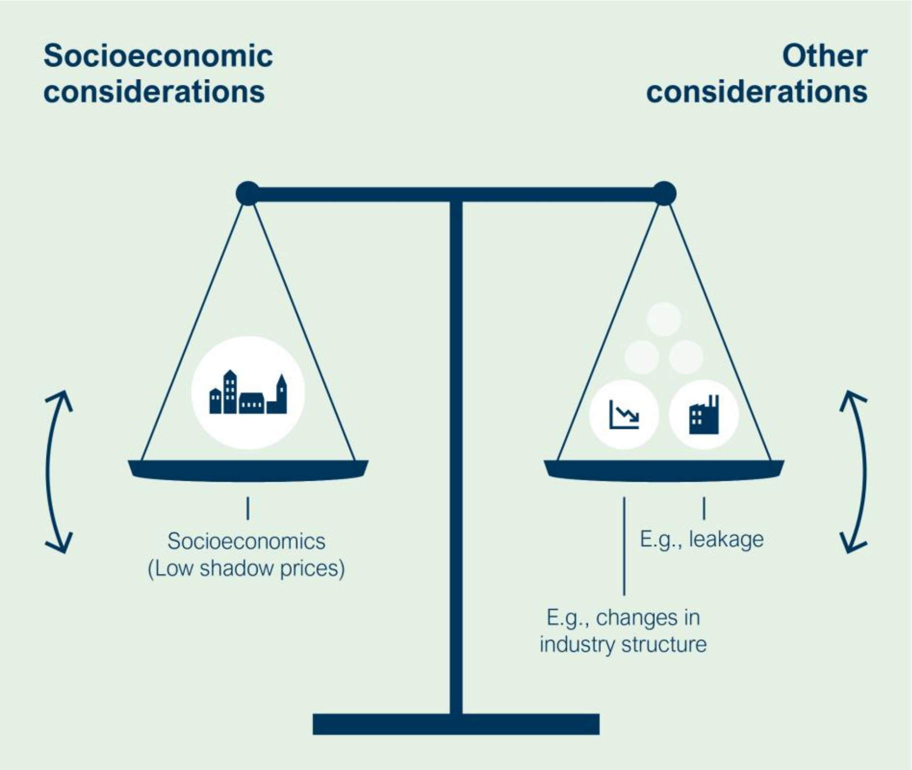
[3] See the Expert Group's first interim report for more detail.

where the CO_2-eq tax is higher for some emission sources than others, the companies subject to the highest tax rates will implement CO_2-eq reductions, which are more expensive than reductions in the companies that have the lowest tax rates. In this situation, the average price of the CO_2-eq reduction will be higher than if all emissions were taxed at the same rate.

Considering special conditions in individual sectors will, therefore, increase the socio-economic costs of achieving a given reduction target, *see Figure 2.1*. The cost increases for the other sectors will be higher than the savings for the sector(s) that receive a relaxation.

Figure 2.1 Balance between the Danish Climate Act's guiding principles



In addition to greenhouse gas emissions, agricultural production has a number of other externalities, including on the environment and health. The externalities are largely linked to the same agricultural activities that give rise to CO_2-eq emissions. This means that when regulations are implemented that reduce greenhouse gas emissions, they also have a positive effect on other environmental concerns and/or public health. These positive side effects will reduce the socio-economic costs of greenhouse gas regulation. For this reason, shadow prices with side effects are reported for each of the models presented.

Consideration of existing occupational structure

A CO_2-eq tax can affect the business structure in agriculture. The introduction of a CO_2-eq tax may lead to declines in production for more CO_2-eq-intensive agricultural production and thereby change the existing business structure through the closure or relocation of agricultural activity. Thus, the Danish agricultural industry will have more activity in less CO_2-eq-emitting branches of production. As a result, there may be a desire to consider the preservation of existing occupational structures by limiting structural changes. This can be achieved, for example, by either lowering the tax rate or by striving for CO_2-eq reductions through technological solutions that do not affect production but instead reduce emissions per unit produced and thus also the burden on the individual farm. This can be achieved by increasing the farmer's incentive to use technological means, e.g. through subsidies or requirements to use certain technologies. However, such tools are socio-economically more expensive to use than a tax.

Consideration for carbon leakage

For products that are produced in competition with foreign manufacturers, the introduction or increase of a national CO_2-eq tax can lead to a weakening of the competitiveness of Danish manufacturers. If some or all of the production of a given product is moved abroad, reductions in CO_2-eq emissions in Denmark will lead to increased emissions abroad (called leakage). *Appendix 7.8* elaborates on the Expert Group's analysis of leakage in agriculture.

The risk of leakage gives rise to a trade-off between the cost-effectiveness of achieving national reductions and the need to reduce global emissions overall. This includes whether to introduce relaxations for businesses with CO_2-eq-intensive production that are also exposed to international competition.

It should be noted that leakage can only occur if other countries have the opportunity to increase their emissions. Countries with a binding obligation to reduce emissions, e.g. through EU commitments, cannot allow their emissions to increase as a consequence of Danish climate policy, unless they over-fulfil their commitments. Conversely, countries that do not have binding commitments can allow their emissions to increase, and it is therefore crucial which countries are expected to take over Danish production, *see Appendix 7.8*.

Concrete models for agriculture

This section presents three different designs of the tax system for non-energy related greenhouse gases in agriculture. The three models reflect different weightings of the consideration of socio-economically low costs versus the consideration of existing business structure in agriculture and limited leakage.

The models lay the foundation for the longer-term tax and subsidy architecture for meeting climate targets after 2030. Thus, it is expected that in the long term, the models will lead to CO_2-eq reductions that are twice as large as the 2030 effect as a result of e.g. afforestation.

In addition, the three models show different pathways to reach the 70 per cent target and the obligations of the EU's Effort Sharing Regulation and LULUCF regulation. The weight of different considerations that the three models represent is ultimately a political choice.

All models are based on the assumption that a socio-economically appropriate regulation of CO_2-eq emissions entails a uniform tax across sectors. It also means that a change in climate ambition should be reflected by changing the tax level uniformly across sectors.

As in the first interim report, the Expert Group assesses that it is not possible to find a model that satisfactorily fulfils the objective of the most cost-effective fulfilment of the 70 per cent target via uniform tax models while at the same time meeting other guiding principles in the Danish Climate Act. This is because CO_2-eq reductions from uniform tax models largely come from structural effects (decline and relocation of production) from cattle farms in particular, which entail a significant burden on the industry and a relatively high risk of carbon leakage.

The Expert Group's models are calibrated so that, with a phase-in from 2027, they are estimated to meet the 70 per cent target in 2030 and Denmark's EU obligations in the Effort Sharing Regulation and the LULUCF Regulation. There are extensive administrative tasks associated with implementing a new tax system for agriculture. It is a prerequisite to be able to phase in the Expert Group's models in 2027 so that a political decision is made relatively quickly on which regulation is desired in order to fulfil the 70 per cent-target in 2030 and Denmark's obligations under the EU's Effort Sharing Regulation and the LULUCF Regulation. A later phasing-in would mean that the models presented would not necessarily fulfil the obligations, and further regulation would be required.

2.2 Common Features of the Models

The work of the Expert Group includes the largest emission sources where there is a close correlation between agricultural and forestry production activities and national emissions.

Broadly speaking, there are three groups of emissions which the Expert Group's models tax or where direct agricultural subsidies are reallocated. These are emissions from:

1. Emissions from livestock. Emissions come primarily from cattle and pigs but also from other livestock, including chickens, pheasants, ducks, sheep, goats, horses, deer, lambs and ostriches.
2. Emissions from spreading manure and agricultural lime on fields. Here, manure can be regulated either by tax or by restructuring direct agricultural subsidies.
3. Emissions from carbon-rich agricultural land.

In addition to the model of the tax structure in agriculture, all models include an expansion of the public funding for the rewetting of carbon-rich agricultural land, an increased subsidy for removal of CO_2 through afforestation and a harmonisation of the current tax on F-gases to the agreed level from *Agreement on the Green Tax Reform for Industry etc.* The common features are explained in more detail in *Box 2.1*.

Box 2.1

Common feature in all models

1) A fee of DKK 10 per tonne of CO_2-eq on emissions from carbon-rich agricultural land, combined with compensation and cost coverage of wetland restoration, corresponding to a shadow price of approx. DKK 570 per tonne of CO_2-eq, *see Section 3.1*. The proposal is estimated to contribute reductions of 0.3 m tonnes of CO_2-eq in 2030, increasing to 1.0 m tonnes of CO_2-eq in 2032. The Expert Group suggests increasing the tax at a revisit in 2027 if the withdrawal rate does not match the assumptions in this report.

2) Subsidies for afforestation of DKK 92,000 per hectare, corresponding to approx. DKK 460 per tonne of CO_2-eq, which is estimated to contribute reductions of 0.1 m tonnes of CO_2 in 2030, increasing to 2.1 m tonnes of CO_2 in 2045 by establishing 250,000 hectares of new forest, *see Section 3.3*.

3) Harmonisation of the tax on F-gases to DKK 750 per tonne of CO_2-eq, so that the tax follows the CO_2-eq tax agreed as part of the *Agreement on Green Tax Reform for Industry etc.*, *see Section 3.4*. It is estimated to deliver reductions of 0.1 m tonnes of CO_2-eq in 2030.

The joint proposals are estimated to collectively deliver reductions equivalent to approx. 0.5 m tonnes of CO_2-eq in 2030.

In relation to the fulfilment of the EU obligations in the Effort Sharing Regulation and the LULUCF Regulation, all models assume the use of LULUCF credits in the period 2021-2025 and up to 8 m ETS allowance cancellations over the entire period 2021-2030 for compliance in the Effort Sharing Regulation. In addition, it is assumed that any overachievement of the Effort Sharing Regulation is used to achieving the LULUCF commitments. The LULUCF credits and ETS allowance cancellations do not contribute to the achievement of national targets of the Danish Climate Act, *see Section 6.2*.

All tax rates are in 2022 prices. It is assumed that the CO_2-eq tax will be phased in gradually from 2027 to 2030, and that the taxes will also be indexed to price developments on an ongoing basis so that they are not eroded by inflation. Finally, the shadow prices of the models are calculated including so-called side effects, i.e. including the recreational value of forests and effects on ammonia emissions and nitrogen leaching, both of which are particularly linked to agricultural fertiliser use, *see Appendix 7.9*.

Note: 1) This assumes that the use of LULUCF credits is prioritised before the use of ETS allowance cancellations. Finally, it is assumed that the flexibility mechanisms are used chronologically, i.e. as soon as and if they can fulfil a reduction need that is not covered by domestic reductions.

Regulation of fertiliser in primary models

The Expert Group's models 2 and 3 include two variants of regulating emissions from fertiliser applied to fields. One option is a tax on fertiliser usage with a base deduction per hectare of agricultural land. The second option is a restructuring of direct agricultural subsidies so that fewer hectare subsidies are granted, and the funds released are used for subsidies for reduced fertiliser usage.

The forms of regulation give different weight to the considerations in the Danish Climate Act. Overall, a fertiliser tax with a base deduction will be the most cost-effective approach to reducing CO_2-eq emissions in general, as the tax provides a uniform incentive to both reduce fertiliser usage for a given crop and to change the crop composition. The base deduction in the tax model partially compensates for the tax payment and mitigates the decline in land value.

A subsidy for reduced fertiliser use will only provide an incentive to reduce fertiliser usage on a given crop, but not an incentive for crop rotation, as the subsidy is given in relation to the existing crop-specific fertiliser norms. Depending on the possibilities for substitution between crop types, this can reduce the greenhouse gas reduction efficiency of the tax model. The subsidy relieves the effect on the farmer's contribution margin, as no tax is paid on the fertiliser that continues to be used. Conversely, the subsidy is fully financed by a reduction in the hectare subsidy, which results in a reduction in the gross margin for all farmers.

As the funding is not dependent on fertiliser consumption but on the farmer's area, it implies a redistribution between farmers in relation to the tax. As with the tax burden, the combination of subsidies and financing via a reduced hectare subsidy leads to a structural effect in the form of a reduction in production and a reduction in land values. In the Expert Group's calculations, the restructuring of agricultural subsidies has a smaller structural effect (smaller decline in production), but a slightly larger decline in land values. The difference in the land value effect depends on the specific assumptions about crop substitution and the effect on cropping intensity of taxing versus restructuring direct agricultural subsidies.

For this reason, two variants will be included in models 2 and 3:
a) Fertiliser tax of DKK 750 per tonne of CO_2-eq with a base deduction per hectare of agricultural land of DKK 200, which corresponds to 50 per cent of the average immediate tax payment for fertiliser per hectare.
b) Restructuring of the direct agricultural subsidy to a subsidy for reduced fertiliser usage of DKK 750 per tonne of CO_2-eq.

In the fertiliser regulation models, the rate does not differ between model 2 and model 3, as a lower tax or subsidy rate for fertiliser usage will largely lead to lower other effects (including technical effects and activity effects), and to a lesser extent reduce structural effects. As shown in *Table 2.1*, the decrease in production in models 1 and 2 is more than twice as large for cattle and pig production relative to crop production. Therefore, in order to maintain the existing occupational structure and minimise the risk of carbon leakage, the rate for livestock should be further reduced before the rate for crop production is reduced. Due to the relatively low structural effects in crop production compared to livestock production, it is assessed that a lower tax/subsidy rate cannot be justified by maintaining the existing business structure and minimising the risk of carbon leakage in agriculture. For that reason, the tax/subsidy rate is the same in models 2 and 3.

Section 3.2 elaborates on the advantages and disadvantages of options a and b, how fertiliser can be regulated and the connection to existing fertiliser regulation.

As an alternative to a tax on fertilisers or a restructuring of direct agricultural subsidies to support reduced fertiliser usage, it may be possible to consider lowering nitrogen norms by a fixed percentage, see the nitrogen regulation from before 2015. [4] The norms are introduced in *Box 2.2* and are currently set in such a way that farmers are able to fertilise to the average private-economically optimal level. In practice, a reduction in norms will mean that farmers will have fewer opportunities to use fertilisers. Olsen and Ørum (2023)[5] argue, among other things, that a reduction in nitrogen standards can be a safer instrument for achieving a specific reduction target than a tax or restructuring of direct agricultural subsidies. Conversely, a lowering of nitrogen standards will create an uneven CO_2-eq regulation, as it does not take into account the individual farmer's reduction cost, thereby increasing socio-economic costs and uncertainty about the CO_2-eq price. Furthermore, reduced norms are likely to result in a different burden on the agricultural sector, shadow price and distribution between farmers than a tax on fertilisers or a restructuring of direct agricultural subsidies.

If the effect of a tax on fertiliser usage of DKK 750 per tonne of CO_2-eq were instead to be achieved through a norm reduction, this would correspond to approx. 7 per

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[4] The reduced nitrogen norm was decided to be repealed with the political agreement on a Food and Agriculture Package of 22 December 2015.

[5] Olsen, J. V., & Ørum, J. E., (2023) "Kort notat vedrørende mulige averse effekter af et tilskud til reducereret kvælstofanvendelse" (Brief note on possible averse effects of a subsidy for reduced nitrogen use), Department of Food and Resource Economics

cent.[6] It should also be noted that farmers do not use their fertiliser quotas in full. If it is assumed that this reduced use will also take place after the introduction of a norm reduction, it is estimated with considerable uncertainty that farmers will not use approx. 10 per cent of the total fertiliser quotas. If reduced nitrogen norms are to be used as an alternative way to reduce fertiliser use, the consequences of this would need to be investigated further.

Box 2.2

The fertiliser quota

A farmer's fertiliser quota is the sum of the nitrogen norms for the farmer's fields. The norms are an estimate of the amount of nitrogen that gives the farmer's economically optimal crop yield at the fertiliser level, where the income from the extra yield can just about pay for the extra cost of the nitrogen fertiliser. The norms are estimated by averaging the optimal fertiliser application across farms. The norms are set by a committee led by Aarhus University, with participation from SEGES, the University of Copenhagen (Department of Food and Resource Economics) and the Ministry of Food, Agriculture and Fisheries of Denmark, and constitute a central element of the existing nitrogen regulation.

The actual average fertiliser usage by farmers is below the norm. This is because the norm is set as an average of the economically optimal use and sets an upper limit on fertiliser usage. This means that some farmers have an economic optimum for their fertiliser usage that is below average and will, therefore, use less fertiliser than the norm allows. The average fertiliser usage indicates a large spread.

The Expert Group has chosen not to include crop management measures in the presented tax models as the CO_2-eq reduction by absorption in the soil's carbon stock is decreasing and reversible[7], *see Appendix 7.5*, and closely linked to the effect of nitrogen regulation. It is therefore recommended that CO_2-eq emissions are included in the new nitrogen regulation currently being prepared. Consider subsidising field management measures to increase the removal of CO_2-eq in fields and achieve a climate effect by 2030. Subsidies for field management measures are included as a possible adjustment screw in *Section 2.8* and are estimated to provide a CO_2-eq reduction of 0.2 m tonnes in 2030 with a marginal shadow price of DKK 700 per tonne of CO_2-eq in 2030. As the effect is diminishing, the CO_2-eq reduction is estimated to be 0.1 m tonnes in 2045 if cultivation practices are maintained.

Overview of the models

An overview of the impacts of the models is shown in *Table 2.1*, including the models' impacts on CO_2-eq emissions in 2030, tax rates, revenue impacts (immediate and after behavioural response) and socio-economic costs, pass-through to consumer prices and change in land values. The individual models and the results are further detailed in the separate sections. *Box 2.3* provides an overview of the main concepts for understanding the model results both in the table and in the review of

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[6] The calculation is based on the average of farmers' total fertiliser quotas for the period 2021-23 (approx. 380 m tonnes of N per year) and the reduced fertiliser use assumed in IFRO's calculations of the effect of a tax.

[7] The build-up of carbon will continue until a new equilibrium is reached in the soil carbon stock that corresponds to the new cultivation practices. Carbon storage in arable farming is reversible, which means that if there is a change in cultivation practices towards a lower input of organic matter, carbon storage will gradually decrease. This will lead to CO_2-eq emissions. To avoid this, it is thus necessary to maintain a given cultivation practice.

the other chapters. In most cases, the modelling results are calculated in the general equilibrium model GreenREFORM[8], which is briefly described in *Box 2.4*.

The three models have different impacts on revenue. Only model 1 entails a net revenue that can be used for e.g. support for transition to greener methods of production or alternatively for support for the dismantling of existing production capacity. Models 2 and 3 requires additional financing due to, among other things, the introduction of a base deduction that significantly reduces tax revenue. In addition, the lower CO_2-eq reductions in these models imply an increasing need to achieve technological reductions via carbon removal through deployment of biochar by pyrolysis in order to meet targets, which also contributes to the financing needs in models 2 and 3.

The 3 models show different paths to reach the 70 per cent target. Together, the tax models form an area of conflicting considerations to a certain extent. In this way, it will ultimately be a political choice how the different considerations are weighted and how the architecture of a CO_2 tax system is arranged.

Table 2.1. Overview of the impact of the models in 2030

	Tax rate in 2030		**CO_2-eq reduction**			**Production volumes and value**		**Costs, revenue and price pass-through**				**Shadow price 1)**	**Change in land values 5)**
	Livestock (base deduction, per cent)	Fertiliser (base deduction, per cent)	2030 (2045)	*Of which structural effects (of which cattle)*	*Of which other effects 2)*	Decrease in production, total	Decrease in production value, total	Immediate burden 3)	Revenue from tax	Revenue after behavioural response and subsidy 4)	Increase in dairy and meat product prices 6)	Avg. incl. side effects	Excl./incl. subsidy for afforestation
	DKK per tonne of CO_2-eq		*m tonnes*			*Per cent*		*DKK bn*			*Per cent*	*DKK per tonne of CO_2-eq*	*Per cent*
Model 1 (Effective tax rate of DKK 750 per tonne of CO_2-eq)	750 (0)	750 (0)	3.2 (5,9)	*1,6 (0,9)*	1.5	15.0	9.8	5.9	3.0	1.2	4	150	-16,8/-8,8
Model 2a (Effective tax rate of DKK 375 per tonne of CO_2-eq)	750 (50)	750 (50)	2.8 (5.5)	*1.0 (0.5)*	1.9	8.9	5.8	3.1	1.5	-0.5	2	250	-6.2/4.1
Model 2b (Restructuring of direct	750 (50)	750 (subsidy)	2.6 (5.3)	*0.7 (0.5)*	1.9	6.0	4.2	2.5	1.4	-0.7	2	325	-8.4/2.8

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[8] Impact assessments for the tax on livestock, fertiliser, and liming are fully calculated in GreenREFORM, as are the technology requirements in models 3a and 3b. For subsidies for afforestation and the restructuring of direct agricultural subsidies to reduced fertiliser usage, the shadow prices for these measures are based on partial estimates outside the model. The proposed regulations of carbon-rich agricultural land, F-gases and biochar by pyrolysis are calculated outside the model.

agricultural subsidies)													
Model 3a (Effective tax rate of DKK 125 per tonne of CO_2-eq)	250 (50) / 125 (0)	750 (50)	2.6 (5.3)	*0.6* *(0.3)*	2.0,	5.6	3.5	1.9	1.0	-2.0	1	475	-3.8/7.2
Model 3b (Restructuring of direct agricultural subsidies)	250 (50) / 125 (0)	750 (subsidy)	2.4 (5.1)	*0.3* *(0.2)*	2.0	2.6	1.9	1.3	0.9	-2.1	1	575	-5.5/6.0

Note: Rates and shadow prices are rounded to the nearest DKK 25 per tonne of CO_2-eq. Totals may differ from the sum due to rounding. Rates are shown in 2022 prices, and revenue effects are shown in 2023 levels. It is assumed that the taxes are continuously indexed with the general price level. The calculations include a tax on pigs, cattle and poultry. The CO_2-eq reduction from poultry is rounded to 0.0 m tonnes and is therefore not included in tables. Other animals (sheep, horses, etc.) account for less than 2 per cent of agricultural emissions and are therefore set to zero for calculation purposes.
1) The socio-economic costs are measured in factor prices. The calculations of the socioeconomics and shadow prices do not include improvements in terms of trade and thus do not include gains from price effects that occur at the expense of other countries. The reduction in externalities in the form of environmental and health effects and the benefits from reforestation are included in the socio-economic costs. It is impossible to calculate the socio-economics of an unspecified subsidy fund for conversion/investment aid for new technologies.
2) Other effects cover technical effects (reductions that do not affect the scope of production, but reduce emissions per unit produced, e.g. via feed additives for cattle, biochar by pyrolysis, etc.) and activity effects (e.g. change from agricultural land to forest) and rewetting of carbon-rich agricultural land.
3) The immediate burden is defined as the impact of a tax change on CO_2-eq-emitting companies before the companies start to change their behaviour. It is basically calculated as the product of the company's CO_2-eq emissions and the tax increase. The immediate burden includes the realised technology costs for the technology requirements for feed additives and tent covering with floating layers in models 3a and 3b. The costs are associated with uncertainty due to low technological maturity.
4) In the calculation of the revenue according to behaviour and subsidies, the government expenses associated with subsidies for forests, carbon-rich agricultural land and biochar by pyrolysis are included. It should be noted that a total of DKK 9.4 bn extra has been allocated for the rewetting of carbon-rich agricultural land. The funds are calculated here equally distributed between 2025-2032, when the set-aside is expected to occur.
5) The land value changes are excl. effect from set-aside and wetland restoration of carbon-rich agricultural land. The effect from subsidies for afforestation is under the assumption that land converted to forest has an average cultivation value compared to agricultural land in rotation.
6) The average price increase from dairy and slaughterhouse products is calculated as the price changes on the Danish dairy and slaughterhouse food deliveries to Danish households in 2030 weighted by the households' expected consumption of these foods in 2030 before they have adjusted their consumption to the tax.
Source: Own calculations

Box 2.3

Key terms in connection with model calculations

Most calculations in the report are based on the GreenREFORM model. This is described in more detail in *Box 2.4*.

The immediate burden is defined as the impact of a tax change on CO_2-eq-emitting companies before the companies start to change their behaviour. It is calculated as the product of the company's CO_2-eq emissions and the tax increase.

Revenue after behavioural response is defined as the revenue effect of a tax change, taking into account changes in behaviour and the effect of the tax change on other government revenue and expenditure. It is this revenue that can be allocated to, for example, tax reductions and financing subsidies. In other contexts, revenue after behavioural response is called the impact on government finances and revenue after statics effects and behavioural response.

The socio-economic cost indicates the value of the welfare loss experienced by society as a result of increased taxation and subsidies. The socio-economic cost per tonne of CO_2-eq is also called the shadow price. A distinction is made between the average shadow price, which covers the total socio-economic cost per tonne of reduced CO_2-eq, and the marginal shadow price, which covers the socio-economic cost of reducing one more tonne of CO_2-eq. The calculations of the socioeconomics and shadow prices do not include improvements in terms of trade and thus do not include gains from price effects that occur at the expense of other countries. The reduction in externalities in the form of environmental and health effects and the benefits from reforestation are included in the socio-economic costs.

When a CO_2-eq tax is introduced, the CO_2-eq reductions can be calculated in two types of reductions: structural effects and other affects.

Structural effects (alternatively paradigm shifts in businesses) cover reductions from changes in production or relocation and possible cross-border trade. This happens because a tax increase makes Danish companies less competitive relative to foreign companies and therefore forces them to reduce or relocate their production or because CO_2-eq-intensive products become more expensive relative to CO_2-eq-light products, causing consumers to shift their consumption towards CO_2-eq-light products. Large structural effects will usually indicate a significant risk of carbon leakage.

Other effects cover technical effects (reductions that do not affect the scope of production but reduce emissions per unit produced, as a result of e.g. feed additives for cattle, storage technologies, biochar by pyrolysis, etc.) and activity effects (e.g. change from agricultural land to forest or set-aside and wetland restoration of carbon-rich agricultural land).

Land value decline covers the land value effects of a given tax model, where there will be changes in the coverage contribution on the land, which leads to changes in land use and valuation of the land as a result of the land changing to the best economic alternative after a tax reform (e.g. fallowing, wet land restoration of carbon-rich agricultural land or afforestation).

Change of activity: Covers change in type of activity, e.g. change between animal types, change in land use, etc., without production decline and decrease in quantity without a decrease in production, such as optimisation and change to crop type with less fertiliser consumption, but unchanged amount of crop production.

Degree of price pass-through covers how much of the immediate burden is estimated to be passed on in higher (consumer) prices.

The various concepts and calculation methods, including the potential for agriculture to transition to less CO_2-eq-intensive production, which form the basis of the modelling calculations, are further elaborated in documentation notes and sensitivity analyses. In addition, there are a number of uncertainties that are addressed in *Section 3.5*.

Box 2.4

Brief description of GreenREFORM

Most impact assessments of the models are made in GreenREFORM, which is a general environmental and climate economic equilibrium model that can assess the environmental and climate effects of economic activity, as well as the economic effects of environmental and climate policy initiatives. The model has been 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. Sub-models have been created for the waste, energy, agriculture and transport sectors, as well as for technological transition elements.

The main model is a general equilibrium model describing Denmark's overall economic activity and combining results from the sub-models. GreenREFORM has a high level of detail in the description of production in the economy in terms of industry breakdown and detailed assumptions about market conditions etc. In the main model, the production and consumption of energy is described explicitly in physical quantities distributed across 27 energy products with associated emissions of 14 greenhouse gases.

GreenREFORM's agricultural model consists of 11 agricultural industries representing different branches of agricultural production. Separate production functions are used for animal and vegetable agriculture, respectively. To capture the interdependence between production branches, an explicit modelling of non-market production and consumption of livestock manure, roughage and bedding within agriculture has been added. Land is added as a production factor for crop agriculture, and non-energy emissions from agriculture are linked to the different inputs that give rise to the emissions. In addition, the relationship between agriculture and LULUCF emissions has been modelled through a model for LULUCF emissions, where agricultural land use is included as an input factor.

The Expert Group has further qualified the GreenREFORM model, where, for example, the assessment of export elasticities is based on recent empirical economic literature. The Expert Group's version of GreenREFORM and a more detailed description of GreenREFORM and the modelling of agriculture can be found on the GreenREFORM website (**https://dreamgruppen.dk//groenreform/ekspertgruppe-for-groen-skattereform-2024**).

The GreenREFORM model is thus used to quantify the expected effects of the different models, and as with all economic models, there is uncertainty associated with the model's results. *Section 2.7* presents and discusses sensitivity analyses of, among other things, the export elasticities used.

2.3 Model 1: Cheap Emissions Reductions

As mentioned, model 1 is a socio-economically cheap model, where the reductions are achieved with a uniform tax of DKK 750 per tonne of CO_2-eq, corresponding to the tax in the part of the industry that are currently not regulated under the EU ETS. Model 1 introduces a tax of DKK 750 per tonne of CO_2-eq on emissions from livestock and fertiliser usage. The model fulfils both the 70 per cent target and the EU obligations in the Effort Sharing Regulation and the LULUCF Regulation, *see Table 2.2*

In the model, all emissions from agriculture are subject to the same tax. This provides the cheapest reductions within agriculture and for society as a whole. The other models will lead to higher socio-economic costs of regulating emissions from agriculture. The counterpart is that in this model, there are large structural effects in the form of a decline in animal production in particular, and that these effects entail a risk of carbon leakage. The model involves a shift in activity from animal feed production to other crop production, which in itself does not impact the CO_2-eq emissions, which instead primarily arise from the reduction in livestock production. This shift in production is not estimated to significantly affect the overall supply of calories to the world market from Denmark, *see Appendix 7.10*.

Production, employment and consumer price

The model implies a decrease in agricultural production of 15 per cent, driven mainly by a decrease in cattle and pig production of 20.2 per cent and 17.7 per cent respectively. The decline in production will decrease employment in the food and agriculture industry by around 8,000 full-time employees in 2030. This corresponds to a decrease of approx. 10.2 per cent of those employed in agriculture and the food industry in 2030. The decline in employment is offset in 2030 by an increase in other industries with less greenhouse gas-intensive production. At the same time, the lower production means that consumer prices for goods from Danish slaughterhouses and dairies increase by an average of just under 4 per cent, *see Table 2.4*.

Table 2.2 Main results of model 1

Model 1 Cheapest emissions reductions: 750 per tonne corresponds to tax level in industry etc. not subject to ETS.

CO_2-eq reductions		**Costs and revenues, 2030**		**Shadow prices, change in production, change in employment and change in land values, 2030**		**Fulfilment of climate goals incl. decided actions**	
2030 (2045)	3.2 (5.9) m tonnes	Immediate tax burden	DKK 5.9 bn	Average shadow price (incl. side effects)	DKK 150 per tonne	70 per cent target	124 per cent
Share from structural reductions (cattle)	52 (30[1)]) per cent	Revenue from tax	DKK 3.0 bn	Decrease in production, total	15 per cent	Fulfilling the EU's Effort Sharing Regulation	100 per cent
Share from other reductions	48 per cent	Revenue after behavioural response and subsidy	DKK 1.2 bn	Change in employment, total	-8,000 full-time employees[3)] (-10.2 per cent)	Delivering on EU LULUCF commitments (budget target 2026-2029/point target 2030)	100 per cent
Subsidies for negative	0.1 m tonnes (2.1)			Change in land values, excl. /incl.	-16.8/-8.8 per cent		

emissions2) 2030 (2045)		subsidies for afforestation	

Note: See *Table 2.1*.

1) Share from structural reduction from cattle indicates that 30 per cent of the 2030 emissions of 3.2 m tonnes of CO_2-eq comes from a reduction in cattle production.

2) Subsidies for forestry.

3) Total employment decline in agriculture and related industries. The decline in employment is offset in 2030 by an increase in other industries with less greenhouse gas-intensive production.

Source: Own calculations

Composition of greenhouse gas reductions

The 15 per cent reduction in production means that more than half (52 per cent) of the total reduction in greenhouse gas emissions comes from structural effects. Of this, 30 per cent of the total reduction comes from structural effects from cattle production. The high structural effects are due to the economically viable technological reductions being limited, *see Appendix 7.5*. This shows that at a tax level of DKK 750 per tonne of CO_2-eq, it is estimated that only the potential effects from the technologies feed additives and tent covering with floating layers will come into play. The average shadow price for model 1 is equal to DKK 150 per tonne of CO_2-eq. Compared to other areas, such as transport and industry, these are cheaper reductions as measured by the shadow price. This is partly due that reductions from structural effects typically having low socio-economic costs.

Land value decline and compensation

The lower production and production value also mean that the value of agricultural land falls. The isolated effect of the tax is a decrease of 16.8 per cent. The Expert Group's proposal for a subsidy for afforestation of DKK 92,000 per hectare stimulates the demand for land and increases the production value. Both effects increase the value of land and thereby act as partial compensation for the existing farmers. Overall, however, there is still a decrease in land prices of 8.8 per cent. Subsidies for afforestation also have a positive CO_2 effect on the net absorption from forests, which is limited to 0.1 m tonnes by 2030. By 2045, the contribution grows to 2.1 m tonnes of CO_2. Finally, the subsidy for afforestation means that the goal of establishing 250,000 hectares of forest is expected to be realised.

The tax imposes an immediate burden on agriculture (i.e. the cost of the tax with unchanged production) of DKK 5.9 bn. After shifts in production etc., the tax is expected to generate revenue of DKK 3.0 bn. If subsidies for afforestation and rewetting of carbon-rich agricultural land are taken into account, there is still a revenue of DKK 1.2 bn that can be returned to farmers.

It is fundamentally difficult within the existing tax system to return the revenue in a targeted way to the branches of agriculture that are hit hardest by the CO_2-eq tax. These companies will typically not have a correspondingly large tax payment compared to the burden from the CO_2-eq tax. In addition, a large proportion of farmers are on a business tax scheme, which includes not paying corporate tax, for example. Compared to the first interim report, it has thus been decided not to reverse the revenue from a reduction in corporation tax.

In model 1, it is instead assumed that the net revenue of DKK 1.2 bn are returned to the industry as a subsidy for capacity closure, *see Section 2.10*, or conversion/investment aid for new technologies. The Expert Group has not further specified the subsidy scheme. The design will need to ensure that the subsidy schemes do not counteract the CO_2-eq reductions from the tax in 2030 and in the longer term. Therefore, the subsidy should, as a starting point, be designed as a temporary subsidy as with the *Agreement on Green Tax Reform for Industry etc.*

Breakdown of the total effects on farm types

As cattle production is the most CO_2-eq-intensive part of agriculture, the adjustments are greatest for this type of farming. Conversely, the adjustments are the least in scope in crop production, *see Table 2.3*.

Table 2.3. Model 1: Change in production volumes and value, 2030

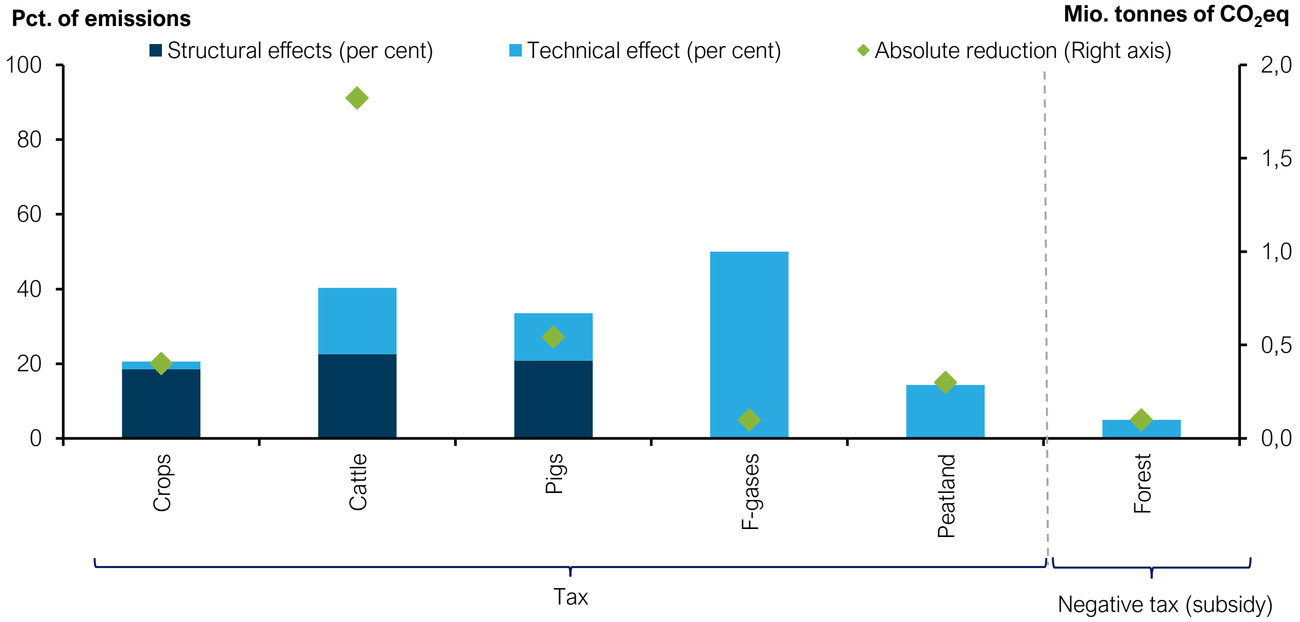
Model	Crop	Cattle	Pigs	Overall
Decrease in production, per cent	7.9	20.2	17.7	15.0
Decrease in production value, per cent	7.6	8.7	13.6	9.8

Source: Own calculations

The changes in the scope of production give rise to reductions in greenhouse gas emissions (structural effects). For cattle production, the structural effects correspond to 22 per cent of non-energy-related emissions, where the structural effects for pig production correspond to 20 per cent of non-energy-related emissions. For crop production, the structural effect is significantly lower and amounts to 9 per cent of the non-energy-related emissions of crop farming, see *Figure 2.2*.

The technological reductions are also greatest for cattle production, where they account for 18 per cent of the non-energy-related emissions. This is because feed additives become profitable to use at a tax level of DKK 750 per tonne of CO_2-eq. For pig production, there are also technical effects on 12 per cent of non-energy-related emissions. This reduction is related to the fact that in this branch of production, technical measures related to slurry handling will also be profitable. The technical effects are significantly lower for crop farming, amounting to 2 per cent, as there are fewer possibilities for technical conversion.

Figure 2.2 Model 1 – Share of structural and technical effects in relation to non-energy-related emissions



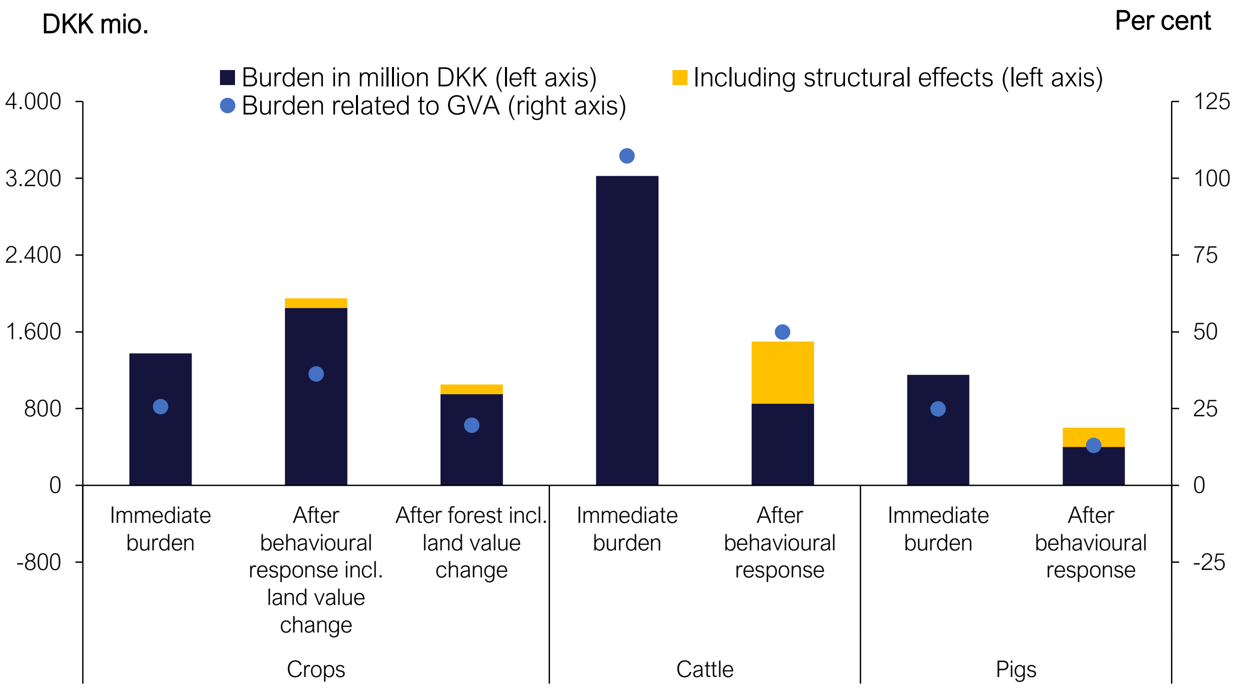
Note: The green diamonds are the reduction in emissions in m tonnes (right axis). The columns cover the proportion of the tax category's basis that is reduced (left axis). Source: Own calculations.

The tax burden on the agricultural sector and the resulting structural effects depend to a large extent on the level of emissions relative to the value added. For cattle production in particular, the immediate burden on business is high both in absolute terms and relative to value added measured by GVA. The immediate load accounts for just over 100 per cent of the GVA in this branch of production. For both crop and pig production, the immediate burden on business is around 25 per cent of GVA, *see Figure 2.3*.

The burden of the CO_2-eq tax increases after the behavioural response of crop producers as a share of the tax on livestock is passed on in higher fertiliser prices and reduced feed prices, thus affecting the earnings of crop producers. Similarly, the burden on crop producers decreases significantly as a result of the afforestation subsidy, which reduces the decline in land values, *see Appendix 7.14*.

In general, the split between livestock and crop production does not correspond to the split between farms with animal production and farms with crop production, as livestock producers own significant amounts of land used for feed and fertiliser application. The split considers each farm type in isolation and does not include these compositional effects. In *Appendix 7.15*, examples of typical farmers for livestock producers are shown where average hectare ownership is included.

Figure 2.3 Model 1 - Burden incl. change in land value in DKK m and in relation to GVA



Note: For crop farming, the burden after behavioural response is calculated based on changes in land value (stated as annuity) and capital loss. For cattle and pigs, the burden is reported in 2030. The burden of the CO_2-eq tax increases after the behavioural response of crop farming, as a proportion of the tax on livestock, is transferred into higher fertiliser prices and reduced feed prices, thus affecting the earnings for plant farming. GVA is calculated including the value of non-market deliveries (livestock manure, bedding and roughage). It should be noted that manufacturers do not have to pay tax for the share of production that is (fully or partially) closed. This means that the burden for the closed part of the production is not included in the burden after the behavioural response (the dark blue part of the columns). This may give rise to the belief that there is a greater opportunity to reduce tax payments by, for example, reorganising production or using technical measures than is actually the case. Therefore, the column after the behavioural response is also illustrated with "incl. structural effect" (the light blue part of the column), which should draw attention to the immediate burden for the part of the production that closed.
Source: Own calculations.

Consumer prices and price pass-through

The behavioural changes that lead to lower production mean that it is possible to sell the reduced volume at a higher price. The prices of products from slaughterhouses and dairies are estimated to increase by 1.6 per cent for the product groups with the lowest price increase and up to 10 per cent for the product groups with the highest price increase, *see Table 2.4*.

Table 2.4. Model 1: Average price increases for goods from slaughterhouses and dairies, 2030

	Cattle slaughter-house	Pig slaughterhouse	Dairy	Overall	Dairy
Average price in-crease, per cent.	10.0	1.6	4.6	3.7	4.6

	500 grams of minced beef	500 grams of minced pork	1 litre of milk		1 litre of milk
Price increases, DKK1)	4.5	0.6	0.6	-	0.6

Note: Calculations are based on price increases from the food industry for private consumption. It should be noted that the price increases are the average price increases for cattle slaughterhouses, pig slaughterhouses and dairies, which is why the table assumes that the products are affected by the average increase of the industries. Please note that the immediate prices are stylistic examples. 1) It is assumed that 500 grams of minced beef, 500 grams of minced pork and 1 litre of milk cost DKK 45, DKK 35 and DKK 13 respectively, including VAT.
Source: Own calculations.

The price increases mean that consumers bear some of the immediate burden. Of the total immediate burden in the model of DKK 5.9 bn, an average of 56 per cent is estimated to be passed on in higher consumer prices.

There is a stickiness in the adjustment of the capital stock in agriculture when a tax is introduced. This means that even if the tax comes into force in 2027 and is phased in towards 2030, it will be a few years before the capital equipment needs to be renewed. The stickiness implies that the tax's full effects on the production adjustment (structural effects) will correspondingly occur on the other side of 2030 as the capital stock is worn out and needs to be renewed.

2.4 Model 2: Partial Handling of Effect on Occupational Structure and Consideration to Carbon Leakage

Model 2 maintains the marginal incentive for CO_2-eq reductions included in model 1, while attempting to preserve the existing occupational structure and reduce the risk of carbon leakage in agriculture to a greater extent than model 1. In addition, the model places greater emphasis on technological solutions.

In this model, the starting point is therefore a lower effective tax rate. In model 2a, the tax on livestock and fertiliser usage is DKK 750 per tonne of CO_2-eq with a base deduction per animal and per hectare of on average 50 per cent of the immediate tax payment. The effective tax rate is thus approx. DKK 375 per tonne of CO_2-eq and the tax level in agriculture is thus equated with the level from the industry's EU ETS from the *Agreement on Green Tax Reform for Industry etc*. Model 2 meets both the 70 per cent target and the EU obligations in the Effort Sharing Regulation and the LULUCF Regulation.

Base deduction in tax on greenhouse gas emissions from livestock and fertilisers

Model 2a is based on a marginal rate of DKK 750 with an effective tax rate of approximately DKK 375 per tonne of CO_2-eq for emissions from livestock and fertiliser. A tax system with a CO_2-eq tax and a base deduction will provide an incentive at the margin to use technological solutions (e.g. more climate-optimised barns, feed additives, etc.). At the same time, the base deduction will limit the increase in production costs.

1) In model 2a with a tax on greenhouse gas emissions from fertiliser, it is proposed to introduce a base deduction per hectare of agricultural land of DKK

200, which corresponds to 50 per cent of the average tax payment for fertiliser per hectare. This gives an effective tax rate of DKK 375 per tonne of CO_2-eq.

2) In the tax on livestock, a base deduction per animal is proposed so that it amounts to an average of 50 per cent of the tax payment for a given farm. This gives an effective tax rate of DKK 375 per tonne of CO_2-eq. The base deduction is organised according to the same criteria that are included in the tax without a base deduction and is varied across animal types*, see Appendix 7.6.* For example, dairy cows receive a base deduction that is higher than the deduction for beef cattle.

The Expert Group's use of a base deduction is based on an assessment that it provides a better incentive structure for the industry to switch to less CO_2-eq-intensive production compared to a model with a simple lower tax rate without a base deduction, where the immediate tax payment is the same. *Appendix 7.11* compares a model with a base deduction and higher marginal tax with a model with a reduced rate without a base deduction. The result is that CO_2-eq reductions increase and the structural effect and burden decrease by combining a tax of DKK 750 per tonne of CO_2-eq with a base deduction instead of a reduced tax of DKK 375 per tonne of CO_2-eq.

To comply with EU state aid rules, the base deductions are designed to correspond to 50 per cent of the average direct tax payment for fertiliser usage per hectare and per unit of livestock respectively. This should be seen in light of the fact that the base deductions could be considered a tax relief that constitutes state aid. According to EU state aid rules, such state aid may not exceed 80 per cent of the actual tax payment. An authorisation will also require that the Commission finds that the other conditions for approving state aid are met. It is thus expected that the base deductions, including the specific size of the base deductions, will need to be discussed with the European Commission and may also require the Commission's formal authorisation under the state aid rules. The Expert Group's choice of the size of the base deduction is based on an assessment that at a base deduction in the tax of 50 per cent of the immediate tax burden, the majority of the individual husbandries are estimated to achieve a relief of less than 80 per cent of the immediate tax payment (before the base deduction). It should be noted that the Expert Group proposes that the base deductions are designed in such a way that the individual farmer can never obtain a base deduction such that the relief exceeds the mentioned 80 per cent of the immediate tax payment.

Production, employment and consumer price

Model 2a implies a decrease in agricultural production of 8.9 per cent, i.e. the decline in production is about one third lower than in model 1. The decrease in cattle and pig production is 11.4 per cent (compared to 20.2 per cent in model 1) and 11.0 per cent (compared to 17.7 per cent in model 1), respectively. The structural effect on livestock production is thus significantly reduced. The decline in employment is 4,800 full-time employees (compared to 8,000 in model 1) in agriculture and the food industry in 2030, *see Table 2.5.* This corresponds to a decrease of 6.1 per cent of the employed in 2030. As in model 1, the decline in employment will be offset in 2030 by an increase in other industries with less CO_2-eq-intensive production. Like the other structural effects in this animal production, the consumer price increase is approximately halved compared to model 1, so that consumer prices for goods from Danish slaughterhouses and dairies increase by an average of 2 per cent, *see Table 2.7*.

Table 2.5. Main results of model 2a

Model 2a - Partial preservation of the existing occupational structure and consideration to carbon leakage: Tax on livestock of DKK 750 per tonne and base deduction, corresponding to an effective tax rate of DKK 375 per tonne

CO_2-eq reductions		Costs and revenues, 2030		Shadow prices, change in production, change in employment and change in land values, 2030		Fulfilment of climate goals incl. decided actions	
2030 (2045)	2.8 (5.5) m t	Immediate tax burden	DKK 3.1 bn	Average shadow price (after side effects)	DKK 250 per tonne	70 per cent target	113 per cent
Share from structural reductions (cattle)	35 (19[1]) per cent	Revenue from tax	DKK 1.5 bn	Decrease in production, total	8.9 per cent	Fulfilling the EU's Effort Sharing Regulation	100 per cent
Share of other reductions	65 per cent	Revenue after behavioural response and subsidy	DKK -0.5 bn	Change in employment, total	-4,800 full-time employees (-6.1 per cent)	Delivering on EU LULUCF commitments (budget target 2026-2029/point target 2030)	100 per cent
Subsidies for negative emissions in 2030 (2045)[2]	0.3 m tonnes (2.3)			Change in land values, excl. /incl. subsidies for afforestation	-6.2/4.1 per cent		

Note: See *Table 2.1*.
1) Share from structural reductions from cattle indicates that 19 per cent of the 2030 reductions of 2.8 m tonnes of CO_2-eq come from a reduction in cattle production.
2) Forest uptake is 0.1 (2.1) m tonnes and biochar by pyrolysis is 0.2 (0.2) million tonnes in 2030 (2045).
Source: Own calculations

Composition of greenhouse gas reductions

The reduction in production of 8.9 per cent means that in this model, 35 per cent (compared to 52 per cent in model 1) of the total greenhouse gas reduction comes from structural effects. It should be noted that because the marginal tax rate in this model is also DKK 750 per tonne of CO_2-eq, the same technologies as in model 1 are used in this model, i.e. feed additives and tent covering with floating layers. A higher marginal tax rate combined with a base deduction ensures that the ratio between structural effects and technical effects is reduced compared to a proportional tax rate with the same revenue.

The total socio-economic costs measured by the average shadow price are DKK 250 per tonne of CO_2-eq in this model compared to DKK 150 per tonne in model 1. However, these are still relatively cheap reductions in terms of socio-economic costs.

Reductions due to new technology

There is a lower reduction in CO_2-eq emissions due to the lower effective tax compared to model 1. This means that additional measures must be taken to meet the 70 per cent target.

The Expert Group notes that the use of biochar made through pyrolysis is potentially a technology with great potential in the long term. Therefore, the Expert Group suggests that the technology should be supported in this model. Model 2 contains subsidy funds for negative emissions from biochar by pyrolysis, e.g. in the form of support for the storage of biochar produced by pyrolysis in agricultural land, which is estimated to entail a CO_2-eq reduction of 0.2 m tonnes of CO_2-eq in 2030. However, there are significant uncertainties associated with the effect estimate for biochar by pyrolysis, *see Appendix 7.5.* In addition, the environmental and agronomic conditions resulting from the production and use of biochar by pyrolysis, as well as the storage of biochar in agricultural soil, have yet to be determined. The Expert Group notes that it is important in relation to the long-term goal of climate neutrality in 2045 that initiatives are initiated that can result in negative CO_2-eq emissions.

It should be noted that when new technological solutions, such as feed additives and biochar by pyrolysis, are to be included in the national emissions inventory, it requires documentation of the reduction effect and activity data (distribution and operating conditions), *see Appendix 7.5*. For biochar by pyrolysis, sufficient evidence is expected to be available by 2026. It should also be noted that environmental approval for storing biochar in agricultural land to achieve 0.2 m tonnes of CO_2-eq in 2030 is pending.

Land value decline and compensation

The lower production and production value in this model, as in model 1, means that the price of agricultural land declines. The isolated effect of the tax is a decrease of 6.2 per cent compared to a decrease of 16.8 per cent in model 1. In this model, the Expert Group's proposal of a subsidy for afforestation of DKK 92,000 per hectare is more than sufficient to keep land values from decreasing, which increase by 4.1 per cent with the combination of a CO_2-eq tax and a subsidy for afforestation. Existing farmers are thus more than compensated for the decline in land values as a result of the tax.

The introduction of a base deduction corresponding to approx. 50 per cent of the immediate tax payment compensates farmers for part of the tax. It means that the immediate burden (i.e. the cost of the tax with unchanged production) is DKK 3.1 bn compared to DKK 5.9 bn in model 1. After shifts in production etc., the tax is expected to generate revenue of DKK 1.5 bn. Taking into account subsidies for afforestation and rewetting of carbon-rich agricultural land, as well as subsidies for biochar by pyrolysis, the model implies a deficit on public finances of DKK 0.5 bn. Compensation via the base deduction in the tax, subsidies for afforestation, subsidies for rewetting of carbon-rich agricultural land and subsidies for biochar by pyrolysis thus take up more than the full revenue from the tax.

Breakdown of the total effects on farm types

Cattle and pig production face roughly the same percentage reduction in production of around 11 per cent in this model. As in model 1, the structural effects are greatest in animal production, *see Table 2.6*.

Table 2.6. Model 2a: Change in production volumes and value, 2030

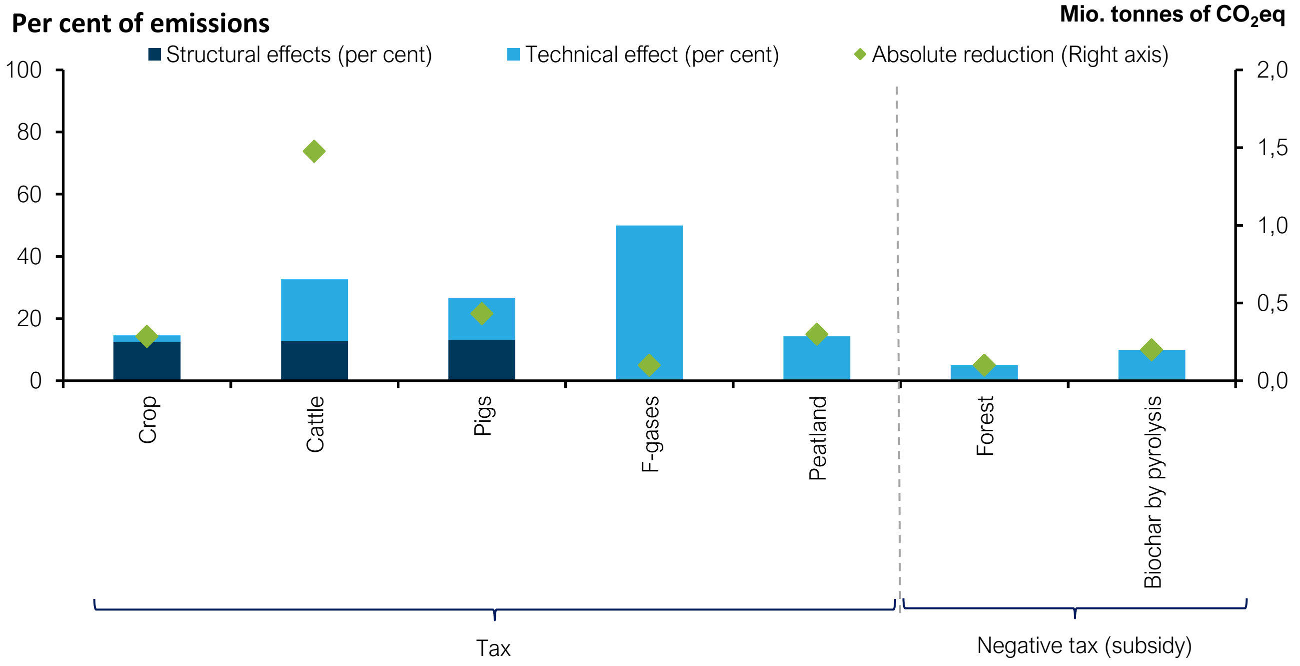
Model	Crop	Cattle	Pigs	Overall
Decrease in production, per cent	4.8	11.4	11.0	8.9
Decrease in production value, per cent	4.5	4.9	8.4	5.8

Source: Own calculations

The changes in the volume of production give rise to reductions in CO_2-eq emissions (structural effects). As in model 1, the structural effects' share of non-energy-related emissions corresponds to the share by which production is reduced for livestock farms. For both cattle and pig production, the structural effect is 13 per cent of non-energy-related emissions. For crop production, the structural effect is also significantly lower, accounting for 6 per cent of non-energy-related emissions, *see Figure 2.4*.

As in model 1, the technological reductions are greatest for cattle production and slightly less for pig production. For both farm types, the technical reduction is of the same order of magnitude as in model 1, as the same technologies are profitable in both models. For crop farming, there are limited technical effects, as in model 1.

Figure 2.4 Model 2a – Share of structural and technical effects in relation to non-energy related emissions



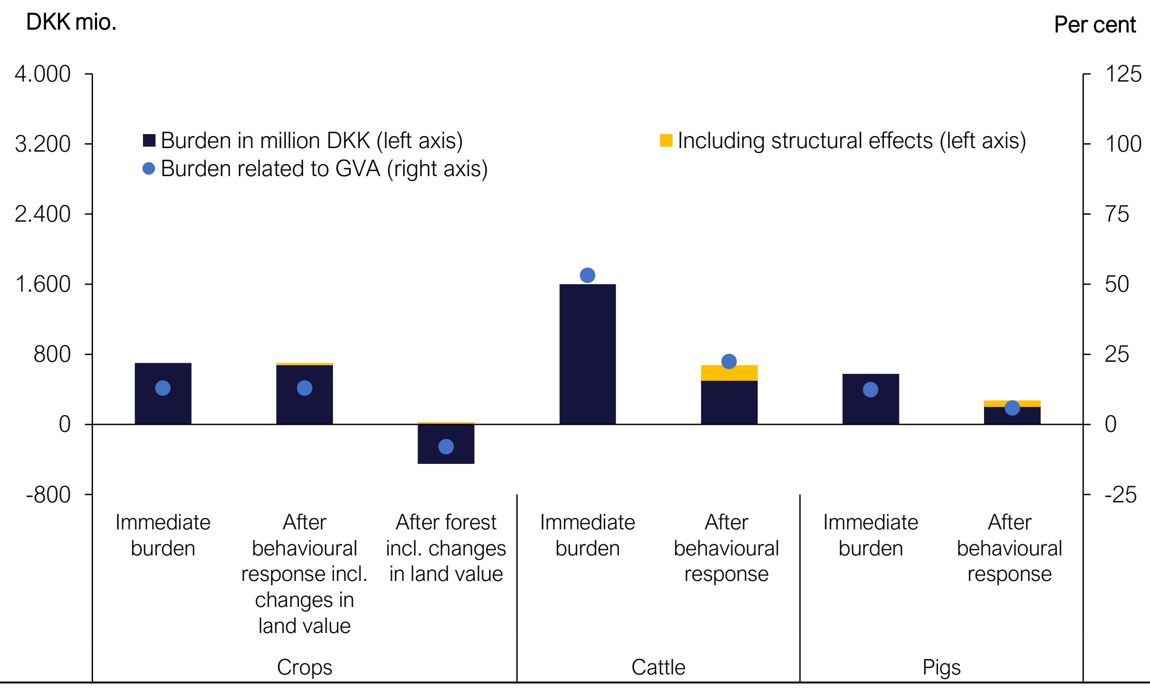
Note: The green diamonds are the reduction in emissions in m tonnes (right axis). The columns cover the proportion of the tax category's basis that is reduced (left axis).
Source: Own calculations.

The immediate burden on business is roughly halved for all three types of farms compared to model 1. The immediate burden on cattle production is large in this model as well, corresponding to more than half of GVA. For both crop and pig production, the immediate burden on business is around 13 per cent of GVA, *see Figure 2.5*.

Unlike in model 1, the burden of the CO_2-eq tax by behavioural response for crop farming is largely unchanged compared to the immediate effect. This is because the reduction in the number of livestock is more limited in this model and the effect on fertiliser prices and feed prices is therefore also more limited in this model. This also means that the combined burden after the behavioural response and afforestation subsidies is negative for crop producers, i.e. the effect of afforestation subsidies on land values has more value for crop producers on average than the cost of the CO_2-eq regulation.

In general, the split between livestock and crop production does not correspond to the split between farms with animal production and farms with crop production, as livestock producers own significant amounts of land used for feed and fertiliser application. The split considers each farm type in isolation and does not include these compositional effects.

Figure 2.5 Model 2a - Burden incl. change in land value in DKK m and in relation to GVA



Note: For crop farming, the burden after the behavioural response is calculated based on changes in land value (stated as annuity) and capital loss. For cattle and pigs, the burden is reported in 2030. The burden of the CO_2-eq tax increases after the behavioural response of crop farming, as a proportion of the tax on livestock, is transferred into higher fertiliser prices and reduced feed prices, thus affecting the earnings for plant farming. GVA is calculated including the value of non-market deliveries (livestock manure, bedding and roughage). It should be noted that manufacturers do not have to pay tax for the share of production that is (fully or partially) closed. This means that the burden for the closed part of the production is not included in the burden after the behavioural response (the dark blue part of the columns). This may give rise to the belief that there is a greater opportunity to reduce tax payments by, for example, reorganising production or using technical measures than is actually the case. Therefore, the column after the behavioural response is also illustrated with "incl. structural effect" (the light blue part of the column), which should draw attention to the immediate burden for the part of the production that closed.
Source: Own calculations.

Consumer prices and price pass-through

As in model 1, the lower production means that it is possible to sell the reduced volume at a higher price for Danish-produced goods. Since the volume reduction is smaller in this model than in model 1, the price increases are correspondingly lower. The prices of goods from Danish slaughterhouses and dairies are estimated to increase by 1.0 per cent for product groups with the lowest price increase to 5.1 per cent for product groups with the highest price increase, *see Table 2.7*.

Table 2.7. Model 2a: Average price increases for goods from slaughterhouses and dairies, 2030

	Cattle slaughterhouse	Pig slaughterhouse	Dairy	Overall	Dairy
Average price increase, per cent.	5.1	1.0	2.3	2.0	2.3
	500 grams of minced beef	**500 grams of minced pork**	**1 litre of milk**		**1 litre of milk**
Price increases on Danish-produced goods, DKK[1)]	2.3	0.3	0.3	-	DKK 0.3

Note: Calculations are based on price increases from the food industry for private consumption. It should be noted that the price increases are the average price increases for cattle slaughterhouses, pig slaughterhouses and dairies, which is why the table assumes that the products are affected by the average increase of the industries. Please note that the immediate prices are stylistic examples. 1) It is assumed that 500 grams of minced beef, 500 grams of minced pork and 1 litre of milk cost DKK 45, DKK 35 and DKK 13 respectively, including VAT.
Source: Own calculations.

The price increases mean that consumers bear some of the immediate burden. Of the total immediate burden in the model of DKK 3.1 bn, an average of 53 per cent is estimated to be passed on in higher consumer prices.

Restructuring of direct agricultural subsidies

This model also includes a variant (model 2b) where no tax is levied on fertilisers. Instead, the direct agricultural subsidies are being redesigned to support reduced fertiliser usage.

As with the tax model, the combination of a subsidy for reducing fertiliser usage and financing via reduced hectare subsidies leads to a structural effect in the form of a reduction in production and a reduction in land values. In the Expert Group's calculations, the restructuring of agricultural subsidies has a smaller structural effect (smaller decline in production), but a slightly larger decline in land values. The difference in the effect on land values depends on the specific assumptions about crop substitution and the effect on cropping intensity of a tax versus restructuring direct agricultural subsidies. A more detailed review of the advantages and disadvantages of taxes and subsidies for reduced fertiliser usage can be found in *Section 3.2*.

2.5 Model 3: Further Preservation of Existing Occupational Structure and Consideration to Carbon Leakage

In model 3, further consideration is given to preserving the existing occupational structure and minimising the risk of carbon leakage in agriculture. The tax on livestock is reduced to DKK 125 per tonne of CO_2-eq. The tax level on emissions from livestock is thus equated with the level from the industry's mineralogical processes etc. from *Agreement on Green Tax Reform for Industry etc.* As in model 2, a rate of DKK 125 per tonne of CO_2-eq can be achieved by either having a marginal tax rate of DKK 250 per tonne of CO_2-eq and a base deduction of on average 50 per cent of the tax payment, or by reducing the tax to DKK 125 per tonne of CO_2-eq. At this tax level, the effects of the two models are largely similar because there are limited technical substitution options in the cost range of DKK 125 to 250 per tonne of CO_2-eq reduction. However, the Expert Group suggests continuing to use the combination of a higher marginal tax rate of DKK 250 per tonne of CO_2-eq and a 50 per cent base deduction in the tax payment, as this can accelerate the use and development of new technical solutions.

Emissions from fertiliser usage are regulated as in model 2. In model 3a, there is a tax rate of DKK 750 per tonne and a base deduction of 50 per cent of the average tax burden, corresponding to DKK 200 per hectare. In addition, as in model 2 there is a model 3b where direct agricultural subsidies are restructured so that they are used to support reduced fertiliser usage.

Production, employment and consumer price

Model 3a implies a decrease in agricultural production of 5.6 per cent. The decline in production is one third of the decline in model 1 and two thirds of the decline in model 2a. The decrease in cattle and pig production is 6.5 per cent (compared to 11.4 per cent in model 2a) and 6.6 per cent (compared to 11.0 per cent in model 1), respectively. The structural effect on animal production is thus significantly reduced compared to both model 1 and model 2a. The decline in employment is approximately 3,000 full-time employees (compared to 4,800 in model 2a) in agriculture and the food industry in 2030, *see Table 2.8*. This corresponds to a decrease of 3.8 per cent of the employed in 2030. As in the other models, the decline in employment will be offset in 2030 by an increase in other industries with less greenhouse gas-intensive production. Like the other structural effects in animal production, the consumer price increase is approximately halved compared to model 2a so that consumer prices for goods from Danish slaughterhouses and dairies increase by an average of 1 per cent, *see Table 2.10*.

Table 2.8. Main results of model 3a

Model 3a – Further preservation of the existing occupational structure and consideration to carbon leakage: Tax on livestock at *either* a rate of DKK 125 per tonne or DKK 250 per tonne and base deduction, corresponding to an effective tax rate of DKK 125 per tonne

CO_2-eq reductions		**Costs and revenues, 2030**		**Shadow prices, change in production, change in employment and change in land values, 2030**		**Fulfilment of climate goals incl. decided actions**	
2030 (2045)	2.6 (5.3) m tonnes	Immediate tax burden	DKK 1.9 bn	Average shadow price (after side effects)	DKK 475 per tonne	70 per cent target	106 per cent
Share from structural reductions (cattle)	24 (12[1]) per cent	Revenue from tax	DKK 1.0 bn	Decrease in production, total	5.6 per cent	Fulfilling the EU's Effort Sharing Regulation	100 per cent
Share of other reductions	76 per cent	Revenue after behavioural response and subsidy	DKK -2.0 bn	Change in employment, total	-3,050 full-time employees (-3.8 per cent)	Delivering on EU LULUCF commitments (budget target 2026-2029/point target 2030)	92/100 per cent
Subsidies for negative emissions in 2030 (2045)[2]	0.9 m tonnes (2.9)			Change in land values, excl. /incl. subsidies for afforestation	-3.8/7.2 per cent		

Note: See *Table 2.1*.

1) Share from structural reduction from cattle indicates that 12 per cent of the 2030 emissions of 2.6 m tonnes of CO_2-eq stem from production decline in cattle production.

2) Uptake from forestry amounts to 0.1 (2.1) m tonnes and biochar by pyrolysis amounts to 0.8 (0.8) m tonnes in 2030 (2045).

Source: Own calculations

Composition of greenhouse gas reductions

The reduction in production of 5.6 per cent means that the structural effects' share of the total greenhouse gas reduction in this model is 24 per cent (compared to 35 per cent in model 2a). At the same time, the total CO_2-eq reduction as a result of the tax is approx. 0.8 m tonnes lower than in model 2a. This means that there is a need to achieve CO_2-eq-increasing effect from technological means. The technical effect of 75 per cent of the total reductions cannot be achieved through cost-effective measures, but is instead based on a combination of requirements and subsidies.

The socio-economic costs measured by the average shadow price are DKK 475 per tonne of CO_2-eq in this model compared to DKK 250 per tonne in model 2 and DKK 150 per tonne in model 1. The significant increase is due to the fact that technological measures used to achieve the overall reductions in this model are expensive compared to reductions achieved by a tax.

Requirements for selected technologies

A tax on emissions from livestock production of DKK 125 per tonne implies that the tax in itself does not provide sufficient incentive for the use of feed additives and tent covering with floating layers. In model 2, these technologies contribute reductions of 0.5 m-0.7 m tonnes of CO_2-eq in 2030 across the two variants of model 2.

To achieve the stated emission reduction objectives, model 3 incorporates a requirement for farmers to use feed additives and tent covering with floating layers or similar storage technologies. A requirement to use a given technology implies that the technologies must be fully utilised, even if the tax levels alone are not sufficient to ensure this. It will lead to higher socio-economic costs than an equivalent model without requirements and a higher burden on affected professions, as it forces farmers to use a specific technology, even if the price exceeds the tax savings arising from a reduction in greenhouse gases.

An alternative option would be to create a subsidy scheme for the technologies in question. It is to be expected that the implementation of subsidy schemes will result in a lesser usage of the technologies than the incorporation requirements, resulting in the climate impact from subsidies is likely being lower than the full technical potential. With a voluntary model based on subsidies, there is uncertainty associated with the expected utilisation of the funds. Conversely, as mentioned above, the burden on the agricultural sector is less with a subsidy scheme than with a requirement.

Subsidy schemes for these technologies could be funded by EU agricultural subsidies, *see Section 6.4*. Requirements can only be financed by EU funds for up to 24 months after a new and more far-reaching national requirement has entered into force compared to existing EU requirements. Support for investment in tent coverings with floating layers will need to be prioritised before a national requirement is implemented.

The Expert Group's choice of requirements in model 3 is based on an overall assessment, where more emphasis is placed on the fact that the requirement provides greater certainty for a given CO_2-eq reduction level. This is in light of the fact that the technologies in question provide a very significant share of the total reduction in emissions from livestock production, which is not provided by a tax level of DKK 125 per tonne of CO_2-eq.

Subsidies for biochar by pyrolysis

The model assumes that technical effects from the use of biochar of 0.8 m tonnes of CO_2-eq will be generated in 2030 if the model is to meet the 70 per cent target. It should be noted that model 3 assumes that approx. 30 per cent of CO_2-eq reductions in 2030 will come from biochar by pyrolysis.

Pyrolysis is a technology with great potential in the long term, which is why the Expert Group suggests promoting the technology as much as possible, subject to outstanding environmental authorisations. However, the reduction effect of pyrolysis is subject to considerable uncertainty, and the environmental conditions resulting from pyrolysis production and ploughing biochar into agricultural land have yet to be determined. Up to 50 20 MW pyrolysis plants will need to be commissioned as soon as possible to achieve 0.8 m tonnes of CO_2-eq reductions by 2030.

The Expert Group suggests that a re-visit be carried out in 2027 to assess the development in the use of biochar by pyrolysis. If the development at this point in time is not expected to lead to a reduction of 0.8 m tonnes of CO2-eq in 2030, the Expert Group recommends that the lacking reductions are alternatively achieved through increased tax rates. Alternatively, implementing a norm reduction in nitrogen regulation that reduces nitrous oxide emissions from livestock manure and commercial fertiliser may be considered. Due to positive environmental and health effects, this regulation is expected to have relatively low socio-economic costs and, as with a tax increase, the effect is more certain than the roll-out of new technology.

Land values and compensation

The reduced CO_2-eq tax means that the effect of the tax on the land values is also lower than in the other models. The isolated effect of the tax is a decrease of 3.8 per cent, compared to a decrease of 16.8 per cent and 6.2 per cent in model 1 and model 2a, respectively. The Expert Group's proposal for a subsidy for afforestation of DKK 92,000 per hectare leads in this model with relatively limited changes in agricultural production to a somewhat larger increase in demand for land than the decrease in demand for land resulting from the reduced tax. Therefore, when a CO_2-eq tax and subsidies for afforestation are combined, the land values will increase by 7.2 per cent. Existing farmers are thus more than compensated for the decline in land values as a result of the tax.

The effective tax rate of DKK 125 per tonne of CO_2-eq on emissions from livestock, compared to DKK 375 per tonne in model 2, reduces the immediate burden (i.e., the cost of the tax at unchanged production) for agriculture as a whole compared to model 2. It is primarily livestock producers who experience this difference between the two models. The immediate burden in model 3a is DKK 1.9 bn compared to DKK 3.1 bn in model 2a and DKK 5.9 bn in model 1. After shifts in production etc., the tax is expected to generate revenue of DKK 1.0 bn. Taking into account subsidies for forestry and rewetting of carbon-rich agricultural land and the increased subsidy for biochar by pyrolysis, the model implies a deficit in public finances of DKK 2.0 bn. Compensation via a base deduction and a reduced tax rate for livestock, as well as via subsidies for forests and rewetting of carbon-rich agricultural land, as well as subsidies for biochar by pyrolysis, thus take up more than the full revenue from the tax.

Breakdown of the total effects on farm types

The reduction of the tax on cattle and pig production compared to model 2 means that the fall in production is reduced to 6.5 per cent (compared to 11.4 per cent in model 2) and 6.6 per cent (compared to 11.0 per cent in model 2) for cattle and pig production, respectively. The lower reduction for livestock farms also leads to a lower reduction for plant farms, even though the tax for that type of farm is unchanged. The decline in production for crop farms is 3.8 per cent (compared to 4.8 per cent in model 2), *see Table 2.9*.

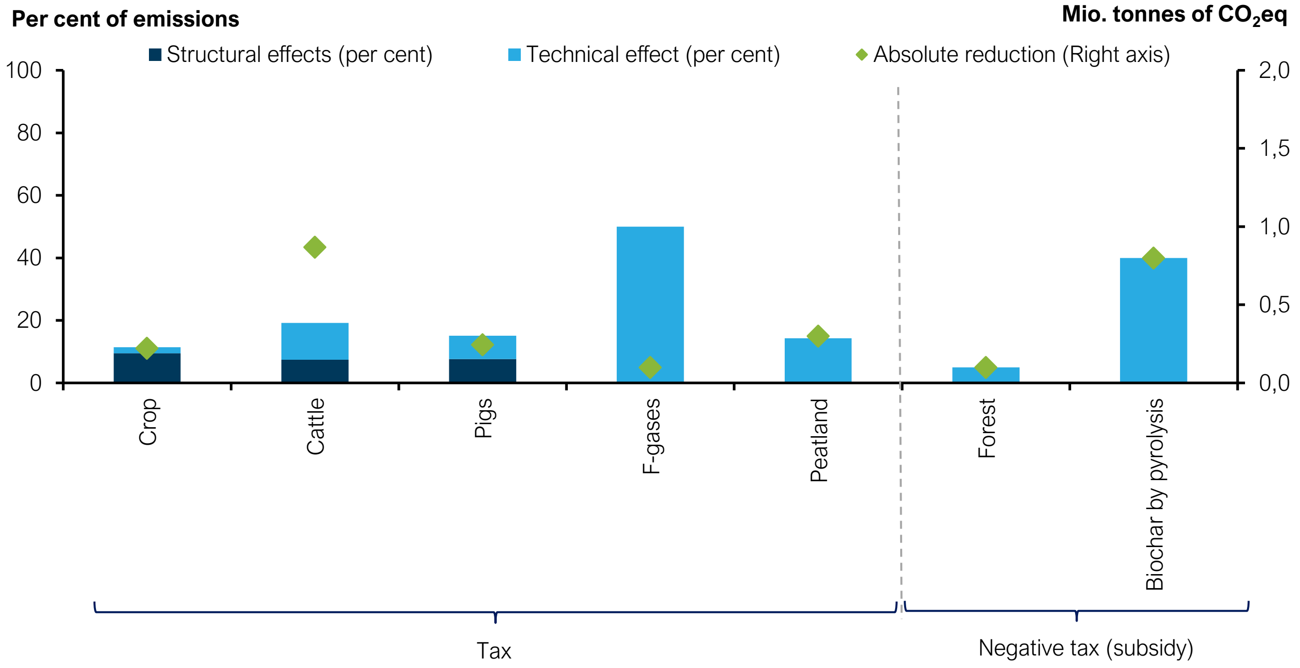
Table 2.9. Model 3a: Change in production volumes and value, 2030

Model	Crop	Cattle	Pigs	Overall
Decrease in production, per cent	3.8	6.5	6.6	5.6
Decrease in production value, per cent	2.9	2.8	5.0	3.5

Source: Own calculations

The changes in the scope of production give rise to reductions in greenhouse gas emissions (structural effects). As in model 2, the structural effects' share of non-energy-related emissions corresponds to the share by which production is reduced for livestock farms. For both cattle and pig production, the structural effect is 7 per cent of non-energy-related emissions. For crop production, the structural effect is only slightly lower than in model 2, accounting for 5 per cent of non-energy-related emissions, *see Figure 2.6*.

Figure 2.6 Model 3a – Share of structural and technical effects in relation to non-energy related emissions

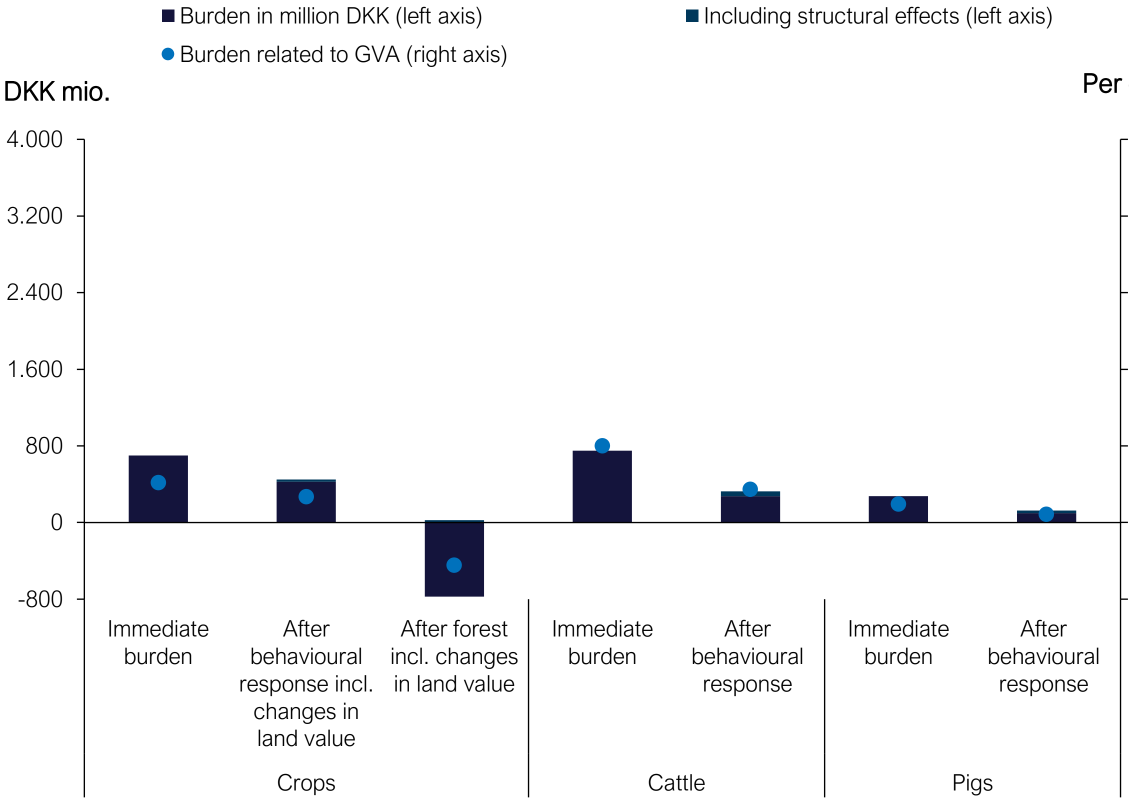


Note: The green diamonds are the reduction in emissions in m tonnes (right axis). The columns cover the proportion of the tax category's basis that is reduced (left axis).
Source: Own calculations.

The lower tax on emissions from livestock also reduces the technical effects, even if requirements for feed additives and tent coverings with floating layers are introduced. This is due to the fact that the incentive for further feed conversions etc. is reduced.

The immediate burden on the agricultural sector is approximately halved for cattle and pig production compared to model 2, amounting to 25 per cent of GVA and 6 per cent of GVA, respectively. The immediate burden for crop producers is unchanged compared to model 2 and amounts to 13 per cent of GVA, *see Figure 2.7*.

Figure 2.7 Model 3a – Burden incl. change in land value in DKK m and in relation to GVA



Note: For crop farming, the burden after the behavioural response is calculated based on changes in land value (stated as annuity) and capital loss. For cattle and pigs, the burden is reported in 2030. The burden of the CO_2-eq tax increases after the behavioural response of crop farming, as a proportion of the tax on livestock, is transferred into higher fertiliser prices and reduced feed prices, thus affecting the earnings for plant farming. GVA is calculated including the value of non-market deliveries (livestock manure, bedding and roughage). It should be noted that manufacturers do not have to pay tax for the share of production that is (fully or partially) closed. This means that the burden for the closed part of the production is not included in the burden after the behavioural response (the dark blue part of the columns). This may give rise to the belief that there is a greater opportunity to reduce tax payments by, for example, reorganising production or using technical measures than is actually the case. Therefore, the column after the behavioural response is also illustrated with "incl. structural effect" (the light blue part of the column), which should draw attention to the immediate burden for the part of the production that closed.
Source: Own calculations

The burden of the CO_2-eq tax after the behavioural response and afforestation subsidies is negative for crop farming, as in model 2, i.e. the effect on land values of the afforestation subsidy has more value for crop farmers on average than the cost of the CO_2-eq regulation. For pig production, the burden on business after the behavioural response is reduced to 2.7 per cent of GVA (compared to 6.0 per cent in model 2). The burden on business for cattle producers is still higher than for the other types of farms and amounts to 10.8 per cent of GVA (compared to 22.5 per cent in model 2).

In general, the split between livestock and crop production does not correspond to the split between farms with animal production and farms with crop production, as livestock producers own significant amounts of land used for feed and fertiliser application. The split considers each farm type in isolation and does not include these compositional effects.

Consumer prices and price pass-through

Since there is only a limited reduction in production in model 3, the opportunities to sell the reduced volume at a higher price are limited. The prices of Danish-produced goods from slaughterhouses and dairies are estimated to increase by 0.6 per cent for product groups with the lowest price increase to 2.8 per cent for product groups with the highest price increase, *see Table 2.10*.

Table 2.10. Model 2a: Average price increases for goods from slaughterhouses and dairies, 2030

	Cattle slaughterhouse	Pig slaughterhouse	Dairy	Overall	Dairy
Average price increase, per cent.	2.8	0.6	1.2	1.1	1.2
	500 grams of minced beef	**500 grams of minced pork**	**1 litre of milk**		**1 litre of milk**
Price increases, DKK¹⁾	DKK 1.4	DKK 0.2	DKK 0.2	-	DKK 0.2

Note: Calculations are based on price increases from the food industry for private consumption. It should be noted that the price increases are the average price increases for cattle slaughterhouses, pig slaughterhouses and dairies, which is why the table assumes that the products are affected by the average increase of the industries. Please note that the immediate prices are stylistic examples. 1) It is assumed that 500 grams of minced beef, 500 grams of minced pork and 1 litre of milk cost DKK 45, DKK 35 and DKK 13 respectively, including VAT.
Source: Own calculations.

As with the other models, the price increases mean that consumers bear some of the immediate burden. Of the total immediate burden in the model of DKK 1.9 bn, an average of 49 per cent is estimated to be passed on in higher consumer prices.

2.6 Summary of the Three Models

As with the first interim report, the Expert Group's analyses show that it is not possible to design a CO_2-eq tax model that fully meets the starting point of the most cost-effective reductions of CO_2-eq emissions from agriculture and forestry and the guiding considerations in the Danish Climate Act and the terms of reference. Taxes on CO_2-eq emissions in production imply both an incentive to reorganise production so that the total CO_2-eq emissions from a given production are reduced, and a relative price increase for products that are CO_2-eq-intensive.

The three models presented take different considerations into account, such as preserving the existing occupational structure in agriculture and minimising the risk of carbon leakage in agriculture. Model 1 equates the tax rate in the agricultural and forestry sector with the rate from the non-ETS sector of industry, where model 2 equates the tax rate with the rate from the EU ETS of industry, and model 3 equates the tax rate with the rate from mineralogical processes etc. All models imply that CO_2-eq emissions are regulated more uniformly in Denmark than is the case today.

Balancing structural effects against other considerations

The results of the three models show that the CO_2-eq-intensive types of farms reduce production volume as a result of the increasing costs of a CO_2-eq tax. Cattle production is reduced by between 20.2 per cent (in model 1) and 6.5 per cent (in model 3). The corresponding reductions in crop production are 7.9 per cent and 3.8 per cent. If you want to minimise structural effects and thereby reduce distributional effects and the risk of bankruptcy, it will have a number of costs in other dimensions. The Expert Group has highlighted a number of factors that should be taken into account when considering the choice of model. These conditions are described below.

Socio-economic costs

Lower structural effects mean that it is necessary to achieve the emission reductions by other means. These will typically be technical measures. A low tax reduces the likelihood of a new greenhouse gas-saving technology becoming competitive. This means that the emissions reduction through technical measures is more expensive than if the reduction was achieved through a tax. It will also require either a requirement/mandate for the technology to be utilised or a subsidy for the introduction of the technology. In the three models, this shift from reductions through a tax to reductions of a technical nature means that the average socio-economic price increases from DKK 150 per tonne of CO_2-eq in model 1 (with greater structural effects) to DKK 475 per tonne of CO_2-eq in model 3 (with the lowest structural effects).

Uncertainty with meeting targets

A higher emphasis on a new technology leads to an increased risk of not meeting the targets as the uncertainty regarding the implementation and development of the technology has a greater impact on the overall emissions reduction. This can be illustrated by the fact that emissions reduction from biochar by pyrolysis is not necessary to meet the 70 per cent target and the EU's Effort Sharing target in model 1, while reduction from pyrolysis accounts for about 30 per cent of the total reduction in model 3.

Public finances

The financing cost for the public sector increases in models that seek to reduce structural effects. This is partly due to a change in effort sharing between farmers and society through compensation measures for farmers, such as a base deduction or subsidies for forestry (which keeps land values under control). However, as mentioned, this is also because increased use of technology to achieve the reductions will typically be associated with public subsidies. The effect on public finances is an improvement of the balance by DKK 1.2 bn in 2030 in model 1 and a deterioration of the balance by DKK 2.0 bn in 2030 in model 3. The surplus in model 1 means that there is room to compensate for the losses in agriculture, but the deficit in model 3 means that the reduction target cannot be achieved without additional funding with the given design of the model.

Environment and health

There is a close correlation between the effect on greenhouse gas reduction due to reduced production and the emission of ammonia and nitrogen. Different models of the change in agricultural production have therefore various environmental and health implications. The Expert Group has calculated the societal value of the environmental, health and recreational improvements resulting from each of the three models. Model 1, which has the largest structural effects, entails a socio-economic gain of DKK 770 m as a result of the effect on the environment, health and recreation. Model 3a (fertiliser tax) has a socio-economic benefit of DKK 490 m on environment, health and recreation. An overview of the effects of the various models is shown in *Table 2.11*

Table 2.11. Socio-economic value of environmental effects (DKK m in 2030)

Model	Nitrogen	Ammonia	Recreation	Total
Model 1	480	100	200	770
Model 2a	380	60	200	630
Model 2b	200	40	200	430
Model 3a	260	40	200	490
Model 3b	170	20	200	380

Note: Totals may not add up due to rounding

Organic production

There are two opposing effects from the models on organic production. Organic producers are less CO_2-eq-intensive relative to conventional producers, which encourages more organic production. Conversely, conventional producers have more options for technical conversion than organic producers, which encourages more conventional production. Whether there will be more or less organic production will depend on which effect dominates. On this basis, it is not immediately possible to assess the overall impact on organic production.

Animal welfare

The Expert Group has not specifically considered the impact of the models on animal welfare. However, it should be noted that the tax can, for example, incentivise increased exports of calves and piglets. It is also noted that the tax provides an incentive to invest in barns that may have lower animal welfare.

Food security

It is not expected that a CO_2-eq tax in isolation will reduce food security in Denmark in any of the models shown, *see Appendix 7.10*. A pure tax of DKK 750 per tonne of CO_2-eq is estimated to result in a decrease in Danish food production for human consumption of 2-4 per cent, corresponding to a total loss of 225 bn-500 bn calories (kcal). The very limited decrease in food production for human consumption, despite the large decline in animal production, is due to an expected shift in activity from feed production to other crop production.

Consumer prices

A CO_2-eq tax will increase agricultural costs, which is partly passed on to consumers through increased consumer food prices. Model 1, which has the largest price increases, implies price increases for products from cattle production of 10 per cent, from dairy production of 4.6 per cent, while pig products are expected to increase by 1.6 per cent. The corresponding price increases in model 3a with the lowest structural effects are 2.8 per cent for beef, 1.2 per cent for dairy products and 0.6 per cent for pork, *see Table 2.12*. The price increases for selected products are shown in *Table 2.13*.

Table 2.12. Average price increases on goods from slaughterhouses and dairies, per cent

	Model 1	Model 2a	Model 2b	Model 3a	Model 3b
Cattle slaughter-house	10.0	5.1	4.3	2.8	2.0
Pig slaughter-house	1.6	1.0	0.7	0.6	0.3
Dairy	4.6	2.3	2.0	1.2	0.9

Note: Calculations are based on price increases from the food industry for private consumption. It is assumed that products are affected by the average price increases for cattle slaughterhouses, pig slaughterhouses and dairies.
Source: Own calculations.

Table 2.13. Price increases on selected Danish-produced products, DKK

	Model 1	Model 2a	Model 2b	Model 3a	Model 3b
500 grams of minced beef	4.5	2.3	1.9	1.3	0.9
500 grams of minced pork	0.6	0.3	0.3	0.2	0.1
1 litre of milk	0.6	0.3	0.3	0.2	0.1

Note: See note to *Table 2.12*. It is assumed that 500 grams of minced beef, 500 grams of minced pork and 1 litre of milk cost DKK 45, DKK 35 and DKK 13, respectively, including VAT.
Source: Own calculations.

Income distribution

The overall conclusion from the analysis of the effect on income distribution is that none of the Expert Group's models have an effect on income distribution as measured by the Gini coefficient.

There are three main effects that drive the changes in real disposable income in the three models. It is noted that all effects are small in the models. The first effect is the direct price effect on agricultural goods, which tends to reduce real disposable income. The second effect is the indirect effect on prices in other sectors due to the lower labour demand in the agricultural sector. This negatively affects labour costs in other companies and leads to a reduction in other prices. In isolation, it increases the real disposable wage. The third effect comes via a slightly lower wage development due to lower demand in the agricultural sector. The lower wage development is also accompanied by a lower adjustment of transfer incomes. This reduces the real disposable income for benefit recipients.

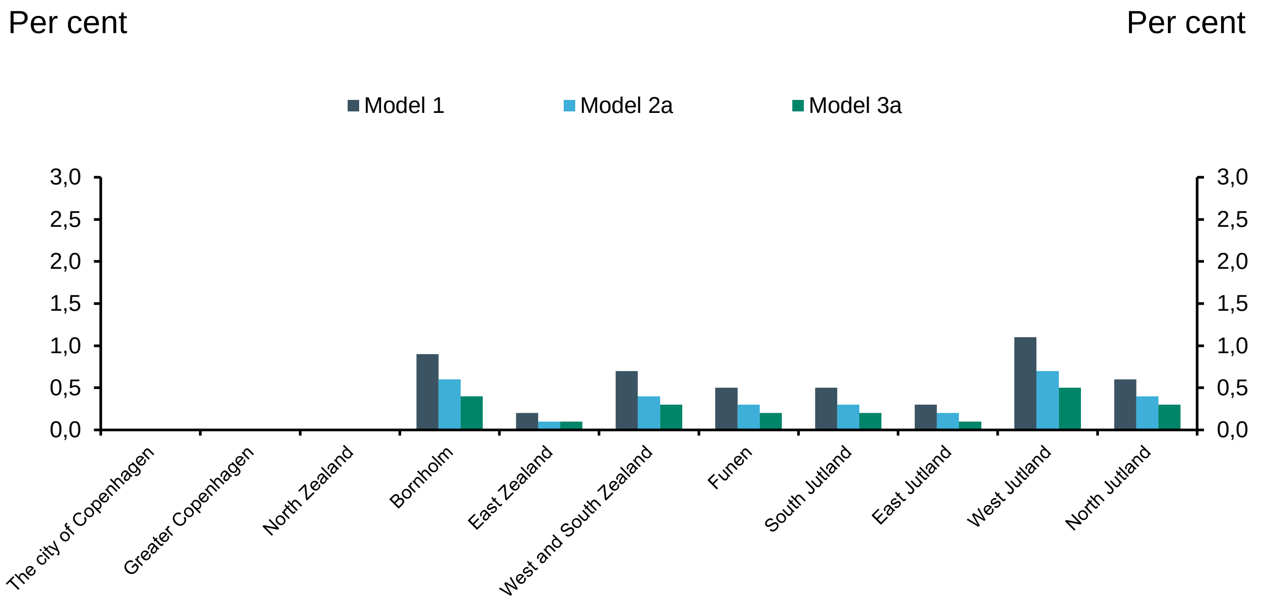
Overall, real disposable income is reduced in all models, as the lower wage development dominates the effect of price changes, *see Section 7.13*. However, the drop in income is limited in all models.

Geographical distribution

Primary agriculture's share of total GVA is limited both for the country as a whole, where it accounts for 2 per cent of total GVA, and by geographical area. Agriculture has the largest share of GVA in West Jutland, accounting for 4.5 per cent of the area's GVA. This is followed by Bornholm, where the share of the island's total GVA is 3.8 per cent. For all other areas, the GVA share is below 3 per cent.

With a relatively low starting point in all geographical areas, the changes in a given area's GVA resulting from the introduction of a CO_2-eq tax on agriculture will be limited. In model 1, where the structural effects are greatest, it is only in West Jutland that the reduction in GVA exceeds 1 per cent. In model 3, where the structural effect is lowest, the effect on GVA is 0.5 per cent. It should be noted that the measured GVA decreases are gross decreases, as they do not take into account the increase in employment in other sectors. It should also be noted that the measured decreases in GVA do not consider the decrease in GVA in the food industry, which, in isolation, means that the GVA decreases are underestimated.

Figure 2.8 Decline in GVA across regions due to production decline in primary agriculture, per cent.



Note: The figure shows the estimated decline in gross value added (GVA) across regions for each of the Expert Group's main models. The figure does not take into account any change in GVA due to production decline in the secondary industry.
Source: Own calculations.

Bankruptcy risk

The three models for reducing greenhouse gas emissions in agriculture mean that the contribution margin of agriculture is reduced, which in isolation implies a decline in land value. Furthermore, the structural changes lead to a capital loss on buildings and machinery for farmers. The loss of value of land, buildings and machinery can hit agriculture harder than other sectors because farms are typically run as sole proprietorships. Therefore, the losses are more concentrated than if the farms had been run in a company form.

Therefore, the combination of capital loss and a reduction in future profit margins can increase the risk of bankruptcy for many farmers. The Expert Group has endeavoured to assess how the three models affect the risk of bankruptcy in agriculture, *see Appendix 7.15*.

As a starting point, 6 per cent of the total turnover in agriculture is estimated to come from the category "farms at high risk of bankruptcy", corresponding to approx. 360 farms. *Table 2.14* shows an estimate of the proportion of turnover in agriculture that immediately moves into the category of farms at high risk of bankruptcy in each of the models presented.

Table 2.14. Immediate changes in bankruptcy threat, in per cent of revenue

	Model 1	Model 2a	Model 2b	Model 3a	Model 3b
Crops	6	1	0	-1	-1
Cattle	25	11	10	1	1
Pigs	12	2	2	0	0
Other livestock	7	0	0	0	-1
Mixed	1	0	0	0	0
Full-time overall	**15**	**5**	**4**	**0**	**0**

Note: The table shows the share of turnover in the individual types of farms that are assessed to be severely threatened by bankruptcy. The calculations for changes in the threat of bankruptcy take into account the immediate capital income effect of the introduction of the CO_2-eq tax and technological reduction options. Adjustment is thus not taken into account.
Source: Own calculations based on SEGES accounting data

Table 2.15. The main results from the model calculations, 2030 effects

Model	Tax rate (before/after base deduction)	Immediate burden[1]	Occupational burden after adjustment[2]	Revenue after behavioural response and subsidy	CO_2-eq reductions, 2030 (2045)	Of which structural effect	Of which other effects[3]	Degree of goal fulfilment	Drop in land value (excl./incl. forest subsidies)[4]	Shadow price[5]
	DKK per tonne of CO_2-eq	*DKK m*	*DKK m*	*DKK m*	*m tonnes of CO_2-eq*	*m tonnes of CO_2-eq*	*m tonnes of CO_2-eq*	*Per cent*	*Per cent*	*DKK per tonne of CO_2-eq*
1	750	5,925	2,425	1,150	3.2 (5.9)	1.6	1.5	124.0	16.8/ 8.8	475/ 150
2a	750/ 375	3,050	1,350	-525	2.8 (5.5)	1.0	1.9	112.9	6.2/ -4.1	525/ 250
2b	750/ 375	2,525	1,325	-700	2.6 (5.3)	0.7	1.9	107.3	8.4/ -2.8	550/ 325
3a	250/ 125	1,900	1,025	-1,950	2.6 (5.3)	0.6	2.0	105.8	3.8/ -7.2	750/ 475
3b	250/ 125	1,300	850	-2,125	2,4 (5,1)	0.3	2.0	99.8	5.5/ -6.0	775/ 575

Note: Revenue effect is rounded to DKK 25 m, socio-economic cost to DKK 10 m and shadow prices to the nearest DKK 25 per tonne of CO_2-eq. Immediate burden and revenue after statics effects and behavioural response are given in 2023 level. The CO_2-eq effects are indicated for 2030.

1) Immediate burden includes the realised technology costs of using feed additives and tent covering with floating layer for models 3a and 3b. For models 3a and 2b, the burden also includes the net cost of using the technologies for fertiliser. The costs are associated with uncertainty due to low technological maturity. Tent covering with floating layer is one of several potential storage technologies. By 2030, tent covering with floating layers could therefore be replaced by other storage technologies with an expected similar climate impact.

2) Burden on business after adaptation only includes the impact of the CO_2-eq tax on liming and livestock, as well as technology costs from feed additives, tent covering and floating layers, and the net cost of using the technologies for fertiliser for models 2b and 3b. The burden on business is calculated in 2030, which is why it differs for crop production from 3.3, 3.5 and 3.7, where the impact is calculated as a discounted annuity for the land value effect.

3) Other effects cover technical effects (reductions that do not affect the scope of production, but reduce emissions per unit produced, e.g. via feed additives for cattle, biochar by pyrolysis, etc.) and activity effects (e.g. change from agricultural land to forest or carbon-rich agricultural land being rewetted).

4) Land value changes exclude the effect of set-aside and wetland conversion of carbon-rich agricultural land. The effect from subsidies for afforestation is under the assumption that land converted to forest has an average cultivation value compared to agricultural land in rotation.

5) Shadow prices are calculated in factor prices excluding/including side effects. Side effects are included for the nitrogen initiative due to reduced fertiliser usage, as well as side effects for ammonia. The calculations of the socioeconomics and shadow prices do not include improvements in terms of trade and thus do not include gains from price effects that occur at the expense of other countries. Socioeconomics are not presented in the table as the models do not result in the same CO_2-eq reductions, which is why shadow prices are considered more comparable for the costs of the models.

Source: Own calculations

2.7 Sensitivity Analyses

Tables 2.17-2.18 show sensitivity analyses based on model 1, model 2a and model 3a with effective tax rates of DKK 750, 375 and 125 per tonne of CO_2-eq on emissions from livestock, as well as the models' respective fertiliser taxes and any technology requirements. The following two parameters are adjusted in the calculations:

1) Different export elasticities in the food industry
2) Different modelling of land supply

Different export elasticities in the food industry

A central part of the impact assessment of a CO_2-eq tax is how exports and imports react to price increases. This determines, among other things, the extent to which Danish production is relocated abroad, *see Appendix 7.8*, and it will also affect, among other things, the pass-through and thus the incidence of a CO_2-eq tax.

The export elasticities can basically be said to reflect the degree of market power that Danish producers are expected to have on the export markets. A high export elasticity implies a low degree of market power, whereas a low export elasticity implies a high degree of market power. No other countries have introduced a CO_2-eq tax in agriculture, which means that the Expert Group has not had access to concrete empirical data on national CO_2-eq taxes on agriculture and forestry. The Expert Group's assessment of export elasticities is therefore based on the general literature on trade reactions to price increases (e.g. through tariffs and other price shocks). There is considerable uncertainty about the size of the export elasticities, which is why the Expert Group in this section includes sensitivity analyses with higher and lower export elasticities in the food industry compared to the central estimate. The selected sensitivity analyses do not significantly change the overall qualitative effects of the main models. However, it can be seen that the effect of a given tax rate on the expected emission reduction is greater the higher the export elasticity. This is because in a situation with higher export elasticity and thus less ability to pass on prices to consumers, the food industry is likely to reduce activity more.

The impact assessments in the report's central estimates are based on Fontagné et al. (2022). Fontagné et al. use a cross-sectional analysis with instrumental variables to estimate trade elasticities at the product level, where tariffs are the instrument for price differences across the countries of the world (the method is explained in *Appendix 7.17).* Tariff rates generally vary between 0-20 per cent and can thus be compared to the relevant cost shocks in the Expert Group's models. Data covers tariffs and trade flows in the period 2001-2016 between 189 exporting countries and 152 importing countries across 5,052 product categories (HS6 grouping). An estimate is made for each product – and for each product, an elasticity is determined that is assumed to be representative of the world's countries as a whole.

As tariff rates are typically relatively constant over time, these estimates can be considered long-term assessments of elasticities. The average export elasticity for the entire agriculture and food industry is 8 when the product-specific export elasticities are compared based on the product composition of Danish exports. This means that a 1 per cent increase in price on average results in an 8 per cent decrease in demand. The elasticities are not country-specific, but express an average export elasticity for the specific product across importing countries. The magnitude of the average export elasticities to comparable to the overall level of export elasticities and the empirical literature in general, see e.g. Hertel et al. (2007) and the review of the literature by Boehm et al. (2023) and Anderson et al. (2004).

The average export elasticities mask a large underlying variation in export elasticities at the product level. In the dairy industry, for example, the average elasticity is 5.46, which means that drinking milk has an estimated export elasticity of close to 10 (lower market power), while butter and cheese have an estimated export elasticity of around 3 and 5 (higher market power). Meat powder, residual products (such as tongues), etc. all have an elasticity above 20. However, weighted together, the export elasticities will be between approx. 5-10.

The export elasticities from Fontagné et al. (2022) are weighted together at the industry level based on the distribution of each industry's exports on the same products. The industry-specific average export elasticities for agriculture and the food industry in the Expert Group's impact assessments are shown in *Table 2.16*.

Table 2.16. Average export elasticities of the agriculture and food industry in the Expert Group's impact assessments

	Average elasticity	Export share
Crop, conventional	5.36	21.5 per cent
Crop, organic	5.36	21.1 per cent
Horticulture	7.50	17.2 per cent
Cattle farming	8.11	2.6 per cent
Pigs	6.41	26.9 per cent
Poultry	6.41	17.2 per cent
Dairy	5.46	50.7 per cent
Bakery	6.67	21.2 per cent
Other food industry	6.93	36.9 per cent
Slaughterhouse, cattle	5.69	53.1 per cent
Slaughterhouse, pigs	12.10	61.3 per cent
Slaughterhouse, poultry	5.84	27.6 per cent

Note: The export elasticities shown are weighted together to industry level based on export estimates at product level. The export estimates at the product level mask a large underlying variation. Note also that the estimates for the animal industries are largely the same for organic and conventional producers, which is why only one overall estimate is reported for these despite the division in GreenREFORM.
1) The database is documented in **BACI: International Trade Database at the Product-level: The 1994-2007 Version** (http://www.cepii.fr/pdf_pub/wp/2010/wp2010-23.pdf)
Source: BACI database[9] and Fontagné, L., Guimbard, H., and Orefice, G., (2022) 'Tariff-based product-level trade elasticities', Journal of International Economics.

In the first sensitivity analysis, the average export elasticity is changed by a proportional change in the elasticity of the underlying product groups. The change is implemented in both directions so that demand for agricultural products is respectively more or less price-sensitive than assumed in the baseline.

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[9] The database is documented in **BACI: International Trade Database at the Product-level: The 1994-2007 Version (http://www.cepii.fr/pdf_pub/wp/2010/wp2010-23.pdf)**

A high price elasticity means that changes in costs are reflected to a greater extent in quantity changes and to a lesser extent in price changes. Therefore, the price elasticity determines how much of the tax payment leads to higher prices, i.e. is passed on to consumers. High price elasticity means that a smaller portion can be passed on to consumers.

In the first scenario, export elasticities for all product groups in the food industry are raised proportionally to an average level of 15 from the initial level of 8. In addition, the "rule of half" is removed from the calculations, which states that consumers have a preference for domestically produced goods and are thus half as price sensitive to domestically produced products, *see Section 3.11.* The level of 15 corresponds to the level of average export elasticity recommended by Copenhagen Economics in their analysis for Agriculture & Food regarding agricultural export and import elasticities.[10] Only 9 per cent of Danish agricultural exports are estimated to have an export elasticity above 15 and only 2 per cent above 20 in Fontagné et al. (2022).

In model 1, where the effect of the tax change is greatest, the price pass-through in consumer prices is approx. 56 per cent with the estimated elasticity of 8 in the baseline, while the high elasticity of 15 leads to a pass-through of 47 per cent.

For quantity changes, the reverse applies in that they become larger when the elasticity increases. In model 1, the effect of the tax on CO_2-eq reduction increases by 0.64 m tonnes from 2.77 m tonnes in the central estimate to 3.41 m tonnes with an elasticity of 15. This corresponds to an increase of over 20 per cent. This includes an almost unchanged CO_2-eq reduction from technical measures, and the larger CO_2-eq reduction can thus be attributed to a relatively large increase in the decline in production. The estimated effects of the tax are thus sensitive to the size of the elasticity, *see Table 2.17*.

For the other two model types, the effect of the introduced tax is smaller than in model 1. In both models, this means that the model results are less sensitive to changes in elasticity in absolute terms. In model 3, the reduction in CO2-eq emissions increases by 0.25 m tonnes if the elasticity is changed from 8 to 15. However, this is a noticeable percentage increase in CO_2-eq reduction from structural effects.

GreenREFORM has published[11] estimates of export elasticities for goods-producing industries at detailed product level (6-digit product codes), based on Feenstra's method.[12] The interpretation of the elasticities is that they can be seen as an average between a short-term elasticity and a long-term elasticity, where the method in Fontagné et al. (2022), which the Expert Group uses, can be interpreted as a long-term elasticity.

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[10] Copenhagen Economics, (2023). "Landbrugs- og fødevaresektorens eksportelasticiteter" (Export elasticities of the agriculture and food sector). The report also recommends that agricultural import elasticities should be at the same level as export elasticities. In GreenREFORM, however, the import elasticities in agriculture are set to be half of the export elasticities. In the sensitivity calculation, the assumption of lower import elasticities is also removed in order to present results that are as close to the CE recommendations as possible. However, it is primarily the higher export elasticities that affect the model's results, which is why only these are focused on in the text.

[11] See "Elasticiteter og markedsvilkår i GrønREFORM" (Elasticities and market conditions in GreenREFORM), and "**Estimering af udenrigshandelselasticiteter i MAKRO" (Estimation of foreign trade elasticities in MACRO), Kronborg, Poulsen and Kastrup 2020** for documentation of the estimation method

[12] Feenstra, R., Luck, P., Obstfeld, M. and Russ, K. (2018), 'In Search of the Armington Elasticity', Review of Economics and Statistics 100(1), 135-150. and Feenstra, R. C. (1994), 'New product varieties and the measurement of international prices', American Economic Review 84, 157–177.

Long-term elasticities are typically assessed to be greater than short-term elasticities because the possibility of adjustments among both consumers and competitors is greater in the longer term. The second scenario uses estimated export elasticities from GreenREFORM, whose elasticities average around 5[13], which from a long-term structural adjustment perspective would be an underestimate.

With an elasticity of 5 on average, the degree of price pass-through in consumer prices in model 1 increases from 56 per cent to 61 per cent.

Similarly, the volume response becomes lower when the elasticity is reduced. In model 1, the effect on CO_2-eq emissions is reduced by almost 0.3 m tonnes if an elasticity of 5 is used instead of 8. In model 3, the corresponding reduction of the CO_2-eq effect is just under 0.4 m tonnes.

A higher export elasticity means that the industry is less able to pass on the CO_2-eq tax in higher sales prices. The consequence of this is that farmers and the food industry bear more of the burden of the CO_2-eq tax, leading to greater land value decline, greater structural effects and thus greater CO_2-eq reductions. At the same time, the revenue from the tax is reduced, as a larger part of the animal agricultural production is expected to cease due to the limited possibilities of passing the tax on to the sales prices.

Lowering the export elasticity instead means that the food and agricultural industry can more easily pass on the tax in higher prices. The result is a relative shift of the tax burden from farmers to consumers, which means a lower land value decline and a lower occupational burden. This implies lower structural effects, which increases the revenue from the tax, but lowers the CO_2-eq reductions.

Changes in the supply of land

The Expert Group's assessment of the effects includes some limited reaction in the supply of agricultural land in rotation as demand changes. The supply response is determined based on the analysis in Olsen et al. (2022).[14] In the second sensitivity analysis, the land supply is changed by fixing the supply of crop rotation land and land values, respectively.

In the case of a fixed land supply, there are minimal changes in the effects compared to the baseline. This is because across all models, there is only a limited amount of agricultural land in rotation. The general effects of the baseline are thus not significantly affected by keeping the amount of crop rotation land fixed.

At the other extreme, it can be assumed that the imposition of the tax reduces the supply of agricultural land so much that the land values remain unchanged. This

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[13] Kirk, J. S. and Hansen, K. H. (2023). "Elasticiteter og markedsvilkår i GrønREFORM" ((Elasticities and market conditions in GreenREFORM), and Kronborg, A. F., Poulsen, K. A. and Kastrup, C. S. (2020) "Estimering af udenrigshandelselasticiteter i MAKRO" (Estimation of foreign trade elasticities in MACRO) for documentation of the estimation method.

[14] Olsen. J. V. and Pedersen MF (2022). "Endogen udtagning af landbrugsjord" (Endogenous set-aside of agricultural land). See also Stewart, L. B., Berg, A. K. and Kirk, J. S. (2023) "Jord som produktionsfaktor i vegetabilsk landbrug" (Land as a production factor in vegetable agriculture) for a more detailed review of the modelling of land supply in GreenREFORM.

means that the farmer is not bound to use a relatively fixed amount of land in their operation. The changes in production will therefore be greater for a given tax change. Such a reaction implies that the burden on business decreases, as the tax is no longer passed on in land values but rather in sales prices. The larger structural effects and CO_2-eq reductions are thus due to both a stronger supply response, which overall results in greater socio-economic costs, and greater CO_2-eq reductions.

Conclusion on sensitivity analyses

The sensitivity analyses carried out indicate that the effects of introducing a CO_2-eq tax on agriculture may give rise to a greater reduction in the volume produced if either the price elasticity of demand is higher or the set-aside of agricultural land in rotation reacts more strongly than assumed in the Expert Group's central estimate. In both cases, the structural effect is greater and greenhouse emissions are reduced more. Conversely, a lower price elasticity or a more fixed land supply will favour lower structural effects and lower greenhouse gas reductions.

The conducted sensitivity analyses do not inherently cover all dimensions of the GreenREFORM modelling properties. Thus, there are various additional uncertainties associated with the model results that are not fully covered by the sensitivity analyses.

In light of the fact that there are no experiences with the introduction of a general CO_2-eq tax on agricultural emissions, the Expert Group considers that there is reason to follow developments closely as a CO_2-eq tax is introduced, and make ongoing assessments of the development with a view on whether the CO_2-eq reductions and the observed development in agricultural competitiveness and economic conditions as a result of the CO_2-eq regulation correspond to what is expected. To the extent that this is not the case, the Expert Group recommends that an assessment be made of the overall CO_2-eq tax structure – and not just that of agriculture – to ensure that the uniform tax structure across sectors is maintained.

Table 2.17. Sensitivity analyses, changed export elasticities in the food industry with the CO_2-eq taxes in models 1, 2a and 3a, 2030 effects

Model	**Effective tax rate in 2030 (livestock/fertiliser)**	**Immediate burden**	**Occupational burden after adjustment**	**Immediate revenue effect after static effects and behavioural response**	**CO_2-eq reductions (excl. decided measures)**	**Of which structural effect**	**Of which other effects1)**	**Price pass-through in consumer prices**	**Drop in land values (excl./ incl. forest subsidies)**	**Shadow price (excluding side effects)**
	DKK per tonne of CO_2-eq	*DKK m*	*DKK m*	*m tonnes*	*m tonnes of CO_2-eq*	*m tonnes of CO_2-eq*	*m tonnes of CO_2-eq*	*Per cent*	*Per cent*	*DKK per tonne of CO_2-eq*
					Model 1					
Standard	750/750	5,775	2,325	3,000	2.77	1.72	1.05	56	16.8/ 8.8	450
Export elasticity = 15	750/750	5,775	2,400	2,425	3.41	2.54	0.88	47	16.8/ 12.2	575
Export elasticity = 5	750/750	5,775	2,175	3,150	2.56	1.48	1.08	61	15.8/ 5.6	400
					Model 2a					
Standard	375/375	2,875	1,250	1,550	2.20	1.04	1.15	51	6.2/ -4.1	450
Export elasticity = 15	375/375	2,875	1,300	1,325	2.61	1.56	1.05	43	6.4/ -1.2	525
Export elasticity = 5	375/375	2,875	1,200	1,625	2.07	0.89	1.18	57	5.3/ -6.8	400
					Model 3a					
Standard	125/375	1,725	975	1,050	1.34	0.64	0.69	46	3.8/ -7.2	450
Export elasticity = 15	125/375	1,725	1,000	925	1.61	0.96	0.65	40	4.2/ -4.8	500
Export elasticity = 5	125/375	1,725	950	1,100	1.25	0.55	0.70	51	3.1/ -9.5	425

Note: Revenue effect is rounded to DKK 25 m, socio-economic cost to DKK 10 m and shadow prices to the nearest DKK 25 per tonne of CO_2-eq. Immediate burden and revenue after statics effects and behavioural response are given in 2023 level. The CO_2-eq effects are indicated for 2030. These effects are not significantly different from the long-term CO_2-eq effects, due to an adaptation time of around 5-6 years. The table only shows the results for the CO_2-eq taxes on fertilisers, livestock and liming, including any bottom deductions and technology requirements for feed additives and tent covering corresponding to the content in models 1, 2a and 3a. The results in the table do not include interactions and effects from subsidies for afforestation, tax on F-gases and the rewetting of carbon-rich agricultural land. In addition, only the results for the a-variants are presented for the sake of clarity. Note that the effects are almost identical for the respective b-variants.

1) Other effects cover technical effects (reductions that do not affect the scope of production but reduce emissions per unit produced, e.g. via feed additives for cattle, biochar by pyrolysis, etc.), activity effects (e.g. change from agricultural land to forest or carbon-rich agricultural land being flooded) and efficiency effects (CO_2-eq emissions per unit produced decrease as a result of a tax).

Source: Own calculations

Table 2.18. Sensitivity analyses, exogenous land supply and land values, for the CO_2-eq taxes in models 1, 2a and 3a, 2030 effects

Model	**Effective tax rate in 2030 (livestock/fertiliser)**	**Immediate burden**	**Occupational burden after adjustment**	**Immediate revenue effect after static effects and behavioural response**	**CO_2-eq reductions (excl. decided measures)**	**Of which structural effect**	**Of which other effects[1)]**	**Price pass-through in consumer prices**	**Drop in land values (excl./incl. forest subsidies)**	**Shadow price (excluding side effects)**
	DKK per tonne of CO_2-eq	*DKK m*	*DKK m*	*m tonnes*	*m tonnes of CO_2-eq*	*m tonnes of CO_2-eq*	*m tonnes of CO_2-eq*	*Per cent*	*Per cent*	*DKK per tonne of CO_2-eq*
					Model 1					
Standard	750/750	5,775	2,325	3,000	2.77	1.72	1.05	56	16.8/ 8.8	450
Exogenous land supply	750/750	5,775	2,275	2,925	2.76	1.73	1.02	57	17.4/ 9.5	475
Exogenous land values	750/750	5,775	1,300	3,275	3.35	2.24	1.12	79	0/ 0	600
					Model 2a					
Standard	375/375	2,875	1,250	1,550	2.20	1.04	1.15	51	6.2/ -4.1	450
Exogenous land supply	375/375	2,875	1,250	1,525	2.19	1.04	1.15	51	6.3/ -4.0	450
Exogenous land values	375/375	2,875	950	1,750	2.51	1.32	1.18	69	0/ 0	525
					Model 3a					
Standard	125/375	1,725	975	1,050	1.34	0.64	0.69	46	3.8/ -7.2	450
Exogenous land supply	125/375	1,725	975	1,050	1.33	0.64	0.70	46	3.8/ -7.2	450
Exogenous land values	125/375	1,725	750	1,225	1.58	0.86	0.72	66	0/ 0	500

Note: See notes to *Table 2.17*

2.8 Dealing with Uncertainty in New Climate Projections

The Expert Group's terms of reference state that different phasing-in scenarios, including sensitivity scenarios, must be made in view of the uncertainty associated with projections, and that uncertainty must be taken into account in the phasing-in scenarios. In addition, the work must consider the fact that technological development is uncertain and that this uncertainty has consequences for the socio-economic costs of meeting the 70 per cent target.

Uncertainty is a basic condition in all projections and economic impact assessments, including climate projections. Thus, it is important that uncertainty does not become an obstacle to making fundamentally sound structural reforms. As a result, it is crucial that the proposed initiatives set the right direction towards 2030 and onwards towards the ambitious climate targets for 2045 and 2050. The Expert Group assesses that a CO_2-eq tax in agriculture, as well as subsidies for e.g. further afforestation and set-aside of carbon-rich agricultural land, as well as the roll-out of biochar by pyrolysis and/or other technologies are necessary and appropriate instruments to fulfil the climate goals that follow from Danish and European legislation.

The climate projection depends on a number of projections in areas such as agriculture, transport and energy, including key assumptions about activity in the Danish economy and uncertainties. The projection covers more than 10 years ahead in time and results may vary from year to year depending on actions and changes in external conditions. The projection results are thus subject to both a general methodological uncertainty and a significant uncertainty associated with external variables, including unforeseen developments in behaviour, technology, prices, weather fluctuations, etc. In addition, changes in calculation methods and emissions factors affect both historical and projection years. This is especially true in the LULUCF area, which is associated with particularly high uncertainty and continuous changes due to new research results. A recent example of this, is the correction of January 2024, where the previously assumed level of emissions from carbon-rich agricultural land was reduced, resulting in the reduction deficit to the 70 per cent target being reduced by approx. 2 m tonnes of CO_2-eq in 2030.

In connection with Denmark's *Climate Status and Outlook 2024*, the forest projections will also be updated with a new methodology, expected to impact total emissions in 2025 and 2030. What is particular for forests is that, even though there is a small uncertainty (0.9 per cent) associated with the projection of the forest area, even minor differences in projections and calculations will have major consequences for net emissions due to relatively large carbon pools, *see Section 3.3*. In addition, new emissions factors for carbon-rich agricultural land are expected towards *Climate Status and Outlook 2025*, which means that the total emissions from carbon-rich agricultural land may be adjusted again. Thus, the estimated reduction deficit may fluctuate significantly from one projection to another solely due to methodological changes or improvements in the calculation basis.

The overall direction of the recommendations is thus clear, but the uncertainty in the projections still needs to be managed in practice, which is why the Expert Group proposes a number of adjustment mechanisms in the following sections in the event of changed assumptions. The initiatives could also be utilised if there is a more general desire to achieve further CO_2-eq reductions, but they would have to be weighed against the additional costs for business and society, which has also meant that the

Expert Group has excluded them from its main recommendations. The adjustment mechanisms are likely to have more relevance in the short term, including the next climate projection, compared to the longer term, as knowledge and development of technologies is constantly changing.

Adjustment mechanisms in the short term

Specifically, the Expert Group recommends a precautionary principle in the form of re-visits and frequent evaluations of the effects in order to ensure fulfilment of the 70 per cent target and other climate commitments, as well as to support sustainable and fair regulation of Danish agriculture. The revisits will also look at the extent to which agriculture's investments in the green transition are commensurate with the tax level.

When making adjustments to climate regulation, an overarching principle can be to minimise uncertainty about framework conditions. This means that tax rates in particular should not be adjusted too often, as this will create uncertainty about long-term investment decisions etc. Furthermore, the principles for levelling taxes across the economy should not be deviated from in the event of changed shortfall estimates – i.e. the general tax levels (including consideration to carbon leakage etc.) should be revisited rather than revisiting the tax in individual sectors and industries.

When reviewing tax rates, the overall tax system in the economy must be considered, including for industry, where the starting point is the harmonisation of the price of greenhouse gas emissions, taking into account the guiding principles of the Danish Climate Act.

The estimated effects on CO_2-eq emissions, burden on the agricultural sector, immediate revenue effect after static effects and behavioural response/expenditure and shadow prices for a number of measures are presented in *Table 2.19*.

Table 2.19. Adjustment mechanisms in the short term and towards 2030

Initiative	CO_2-eq reduction	Burden on business after adjustment	Revenue after statics effects and behavioural response	Shadow price (average excluding side effects)
	m tonnes	DKK m	DKK m	DKK per tonne of CO2-eq
More reductions needed				
Subsidies for field management	0.2	-25	0	530
Requirement for nitrification inhibitors	0.6-0.7	250	275-300	1,200
Increase subsidies for biochar by pyrolysis	0.2	0	-225	1,900
Need for fewer reductions				

Reduced set-aside of carbon-rich agricultural land	-0.3	0	0	570
Reduced subsidy for biochar by pyrolysis	-0.2	0	225	1,900
Remove requirements for feed addition and tent covering	-0.5	-175	125	350

Source: Own calculations.

2.9 Structure of Tax and Subsidies after 2030

In its recommendations, the Expert Group has emphasised that the proposed initiatives contribute to the longer-term goal achievement after 2030, including the objective of climate neutrality in 2045 and the objective of a 110 per cent emissions reduction in 2050 compared to 1990.

When the Expert Group recommends a significant increase in afforestation, it is particularly with the longer term in mind, as it can have a large potential impact in 2045-2050 and beyond. The climate impact in 2030 is thus relatively limited compared to other initiatives in the Expert Group's recommendations. Similarly, the majority of the impact from the rewetting of carbon-rich agricultural land also decreases after 2030.

Long-term climate goals require initiatives that can remove carbon from the atmosphere (so-called negative emissions), such as increased afforestation, biochar by pyrolysis, etc. A fully cost-effective CO_2-eq tax requires that the incentive for reductions also includes negative emissions, which are included on an equal footing with the reduction of positive emissions. As negative emissions are included in national climate targets, they should be subsidised (a "negative tax") at a rate similar to the CO_2-eq tax. This ensures the same incentive to reduce emissions everywhere, so that reduction efforts are made where they are cheapest. Subsidies for negative emissions should in principle be available for all technologies that can ensure negative emissions.

In light of the long-term goal fulfilment, the expert group also recommends subsidising selected technologies that are considered socio-economically expensive or have limited potential in the short term. Technologies such as biochar by pyrolysis are not expected to be adopted on market terms by 2030, even at high CO_2-eq tax levels. Subsidising relatively expensive technologies today can thus contribute to pushing development in a direction that will eventually allow them to be used on market terms.

More generally, the Expert Group expects that initiatives that result in negative emissions can eventually be operated on market terms as the EU develops instruments that can create market-based incentives for this. This includes the Commission's proposal for a certification framework for carbon removal and possible new initiatives in upcoming proposals for EU climate targets and regulation towards 2040.

Here, the Commission is looking at opportunities to extend the polluter-pays principle to emissions and uptake of greenhouse gases from agriculture, including extending emissions trading to the agricultural sector. The ongoing development in EU regulation and market conditions, especially ETS allowances in the agricultural sector, means that tax levels and subsidies must be continuously harmonised in line with new knowledge and regulation.

As stated in *Chapter 6*, in Q1 2024, the European Commission is expected to present a communication on a new EU climate target for 2040, which will set the direction for a new climate architecture in the EU after 2030. In line with the government, the Expert Group recommends that emissions trading should be expanded to the agricultural sector. An EU-wide ETS ensures uniform pricing of CO_2-eq emissions from agriculture, ensuring the same competitive conditions across EU countries.

If an EU ETS were to be introduced for emissions from agriculture, the Expert Group recommends that a reduction in the CO_2-eq tax for the expected ETS allowance price should be introduced, as is the case for companies in industry that are covered by allowances. The specific reduction in the tax on the allowance price for agriculture would depend on the national climate targets in place at the time, the expected development of the allowance price and balancing with the reduction in the CO_2-eq tax on companies covered by allowances in industry etc.

2.10 Compensation

The terms of reference state that the Expert Group must assess different forms of compensation for the industry subjected to the CO_2-eq tax. This should include competitive conditions and the risk of carbon leakage, among other things.

Against this backdrop, the Expert Group has assessed various arrangements for the compensation. As a starting point, it is possible to reduce the burden on business of CO_2-eq-intensive industries by lowering the tax on the industries in question, such as for industrial companies in the EU ETS and in the industry of mineralogical processes etc.

Base deduction

The Expert Group's models 2 and 3 include a base deduction in the tax as a form of compensation. Please refer to *Section 2.4* for a more detailed description.

Restructuring of the direct agricultural subsidy to subsidies for CO_2-eq reduction

For fertiliser usage, a restructuring of direct agricultural subsidies is an alternative to a CO_2-eq tax. It is possible to use the fertiliser standards as a starting point in the existing regulation of fertilisers and provide a subsidy for reduced fertiliser usage, which corresponds to, for example, DKK 750 per reduced tonne of CO_2-eq emissions that a farm falls below the fertiliser standards. For the farmer, the regulation with subsidies for CO_2-eq reduction has the immediate advantage – compared to the tax model – that no tax is payable on the fertiliser that continues to be used. This means that the structural effect is reduced compared to a tax on fertiliser and therefore results in fewer CO_2-eq reductions.

It is assumed that the subsidy is financed by a reduction in direct agricultural subsidies. For the existing farmer, this has a negative effect on overall earnings. The restructuring will also involve a loss of capital, as a reduction in direct agricultural subsidies lowers the value of agricultural land.

Compensation for land value loss through afforestation

A tax on CO_2-eq emissions in agriculture leads to a lower value of land, *see Appendix 7.14.* The consideration of the best socio-economic use of land means that the Expert Group has considered other options for compensating for the loss of land value. The loss of land value is due to the CO_2-eq tax reducing the return on the land. An alternative use of part of the land that entails a higher yield, will therefore help to maintain land values. Partly due to this, as well as other considerations, the Expert Group proposes to significantly increase the support be to convert to forestry. This will help to maintain land values and thus act as compensation for existing owners. At the same time, the increase in forests in Denmark will contribute to lower CO_2-eq emissions in the long term. The subsidy is designed so that the government's target of 250,000 hectares of new forest is met, *see Section 3.3*.

Support for transition to greener methods of production, including support for the dismantling of existing production capacity

The guiding principles of the Danish Climate Act include a consideration for sustainable business development of agriculture as a whole, whereby a profitable production, in general, can be maintained. This may involve considering minimising transition costs to ensure sustainable business development and minimise the loss for existing owners. For this reason, the Expert Group has investigated options for compensating farmers who, for example, want to convert their farms to less CO_2-eq-intensive production, such as crop production.
One tool to support structural changes in agriculture and reduce transaction costs for the individual farmer could be the establishment of a voluntary subsidy scheme for full or partial capacity closure of livestock production.

It is considered immediately possible to obtain EU approval for a voluntary decommissioning scheme for capacity closure based on, for example, environmental or climate considerations. The scheme can be organised so that the capacity closure only concerns the keeping of livestock on a property, allowing other agricultural operations, such as plant cultivation or conversion to forestry, to continue. In general, this entails that the associated areas are not included in the scheme.

For a more detailed overview of the possibility of providing support for the dismantling of existing production capacity, see *Appendix 7.12*.

Handling of Other Emissions

3

3. Handling of Other Emissions

3.1 Rewetting of Carbon-Rich Agricultural Land

Carbon-rich agricultural land[15] is characterised by the accumulation of organic material from plants and similar sources in the top layer of soil (e.g. drained peatlands), *see Appendix 7.3*. Due to high water levels, the decomposition of dead plant material has been very slow. Thus, much of the carbon-rich agricultural land was originally formed in natural wetlands such as bogs and wet meadows. When land is drained to be used as agricultural land, e.g. cultivated fields, or land for livestock, the soil is oxygenated. The combination of a high content of organic matter and oxygen gives the soil's small animals and microorganisms good conditions to break down the organic matter, causing the carbon to decompose and degas, primarily as the greenhouse gas carbon dioxide (CO_2).

The rewetting of carbon-rich agricultural land is important for reducing greenhouse gas emissions from agriculture, and the effort is expected to contribute significantly to achieving the 70 per cent target.

Based on the latest status of the set-aside effort from November 2023, which is calculated including peripheral areas, it can be estimated, using the preliminary assumptions for *Climate Status and Outlook 2024*[16], that set-aside and rewetting of approx. 17,400 hectares of carbon-rich agricultural land excluding peripheral areas[17] has been initiated since the beginning of 2021. Among these, approx. 14,200 hectares are under feasibility study, and approx. 3,200 hectares are under realisation.

It should be noted that this is based on the new mapping of carbon-rich agricultural land published by Aarhus University in early December 2023. The new mapping of carbon-rich agricultural land leads to a significant reduction in the area and thus emissions from carbon-rich agricultural land, resulting in a significant partial reduction in expected emissions by 2030.

[15] Carbon-rich agricultural land (unlike other types of agricultural land) has a very high content of organic matter (>6 per cent), which emits CO_2-eq.

[16] The projection of carbon-rich land uses KF24 assumptions to account for the new mapping of carbon-rich land published by AU in December 2023. The projection with KF24 assumptions is published by DCE, Scientific note 2024 60.

[17] The figure is an estimate based on a conversion from the stated project hectares, which are calculated including peripheral areas in the status from November 2023 based on preliminary assumptions for KF24, which is why the figure is subject to considerable uncertainty.

3.1.1 Stronger incentives for increased set-aside through a combination of tax and subsidy

Barriers to existing set-aside
Various challenges have been identified in the existing set-aside efforts that weaken the work of setting aside land. The effort is voluntary, and if the farmer's financial gain from setting aside carbon-rich agricultural land does not exceed the gain from keeping the land in rotation, the farmer does not have a sufficient financial incentive to participate in the effort. There may also be several other reasons why a landowner does not want to participate in a set-aside project, including the farmer's amenity value associated with maintaining drained land.

A significant barrier to rewetting carbon-rich agricultural land is a lack of support from landowners. Often, a set-aside project will involve a large number of landowners and if some of them do not want to participate, it makes the implementation of the project difficult. In addition, some carbon-rich agricultural land can be difficult to rewet for legal or economic reasons. In addition, some farmers may be hesitant to participate in set-aside efforts due to uncertainty about the future possibilities and consequences of agricultural land set-aside, or because it is difficult to find replacement land in the land distribution.

Stronger incentives
The Expert Group suggests a model with 100 per cent compensation for rewetting costs etc. combined with a tax of DKK 10 per tonne of CO_2-eq from 2030. The Expert Group notes that it is important to monitor the development of the set-aside effort and reassess whether the assumed set-aside effort can be achieved by 2027 at the latest. If the set-aside effort in 2027 is not deemed to deliver sufficient reductions, the tax can be increased.

Overall, it is the Expert Group's assessment that a model with 100 per cent compensation for all costs associated with rewetting, combined with a tax on carbon-rich agricultural land from 2030, will lead to the rewetting of 35,700 hectares of carbon-rich agricultural land excluding peripheral areas by 2030, increasing to 70,000 hectares of carbon-rich agricultural land excluding peripheral areas by 2032. That is, about 14,300 hectares more in 2030 and 44,600 hectares more in 2032 than indicated in the baseline with the assumptions used for *Climate Status and Outlook 2024*. When taking into account that the rewetting of carbon-rich agricultural land will often also affect neighbouring areas – the so-called peripheral areas – a total set aside in 2032 of 140,000 hectares is achieved.

This will result in CO_2-eq effects of 0.3 m tonnes in 2030 and 1.0 m tonnes in 2032 at a shadow price of DKK 570 per tonne of CO_2-eq excluding side effects (externalities and nitrogen) and around DKK 20 per tonne of CO_2-eq including side effects.[18] In the *Agreement on the Green Transformation of Danish Agriculture* from 2021, an expanded technical reduction potential of 0.5 m tonnes of CO_2-eq in 2030 from the effort to rewet carbon-rich agricultural land was designated. The effect in 2030 and 2032 should be seen in light of the fact that it is currently estimated to take five years to set aside land based on the current voluntary schemes. If the combination of tax and subsidy increases support for the initiative, it could result in the rewetting of more land by 2030.

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[18] The figure is calculated based on the assumptions behind the Agreement on Green Transformation of Danish Agriculture.

The effect estimate of a total rewetting of 70,000 hectares is based on the assumption that barriers and any bottlenecks that may arise can be handled, which is considered realistic, *see Section 3.1.8*.

Table 3.1. Realisation of the rewetting of agricultural land, CO_2-eq effects, shadow price and financing

	Wetted lands excl. existing schemes	**Wetted lands incl. existing schemes**	**CO_2-eq effect of proposed model**	**Financing towards 2032, excluding existing schemes**	**Financing towards 2032, including existing schemes**	**Burden[2] of tax**	**Shadow price (excl./incl. side effects)**
	Number of hectares	*Number of hectares*	*m tonnes*	*DKK bn*	*DKK bn*	*DKK m*	*DKK per tonne of CO_2-eq*
2030	14,300	35,700	0.3	-	-	4.3	570/20
2032	44,600	70,000	1.0	9,4[1]	16.7	13.4	

Note: 1) Total financing for 70,000 hectares of carbon-rich land is DKK 16.7 bn, of which DKK 7.3 bn has been allocated in previous agreements, leaving a financing requirement of DKK 9.4 bn. 2) The tax burden corresponds to the immediate burden.
Source: DCE, Scientific note no. 2024 60 based on AU, Peat 2022 map

For comparison, another Expert Group (for set-aside of drained peatlands) was tasked specifically with examining the potential for rewetting carbon-rich agricultural land as part of the Agreement on the Green Transformation of Danish Agriculture. This Expert Group reassessed the area potential for the set-aside of carbon-rich agricultural land from 38,000 hectares (that formed the basis for the Agricultural Agreement) to 52,000-68,000 hectares of carbon-rich agricultural land. The reassessed area potential is based on an updated analysis of barriers to wetland restoration, as well as adjustments in relation to the updated map basis and new knowledge about groundwater levels.

The total set-aside of carbon-rich agricultural land will be determined by the economic incentive to rewet drained lands, which can be affected using a tax or subsidy. EU state aid rules dictate that, as a starting point, you may only compensate for the cost of using a given instrument. An increase in the tax will thus be offset by a reduction in the subsidy/compensation rates. This is due to the fact that landowners are compensated for their loss of income by taking out the carbon-rich agricultural land. A higher tax will affect how much income a landowner loses by taking out the carbon-rich agricultural land and thus affect the possibility of repatriating EU subsidies, as well as reduce the public costs, *see Section 6.4*.

The combination of tax and subsidy should be seen in the light of the fact that the aim of the regulation is to ensure wetland restoration of the land. Generally, a uniform tax on emissions is the most efficient way to ensure climate reductions. But that's not necessarily the case for emissions from carbon-rich agricultural land. A high tax will result in some farmers being relatively heavily burdened by a tax given the high emissions factors. For some farmers, rewetting will be very expensive, so even with a high tax, they cannot rewet the land and remove the tax burden. This creates the risk of farmers going bankrupt if they can neither sell the land nor have the incentive to rewet it. It is proposed that in the future, the state will continue to bear the costs of wetland restoration to ensure that the greatest possible climate benefit is achieved from the effort.

The prospect of a higher tax in the future will appear more credible if it is backed up now by a decision on a low tax rate in 2030. Once a tax has been decided and implemented, it is considered administratively simpler to raise the rate. The tax is proposed to be introduced from 2030 to allow time to establish the necessary administrative basis, including improving the map basis, which is subject to some uncertainty.

3.1.3 Consequences of a tax

A tax of DKK 10 per tonne of CO_2-eq corresponds to approx. DKK 300 per hectare annually in 2030 on average. The tax burden varies from land to land; the land with the highest emissions will trigger an annual levy of up to DKK 500 per hectare. Conversely, the payment for land that emits less will be lower. If the tax is increased to e.g. DKK 100 per tonne of CO_2-eq, this corresponds to almost DKK 3,000 per hectare annually.

After rewetting of carbon-rich agricultural land, there are still limited emissions from the soils that will disappear over time. It is proposed that the tax is removed once the land is set-aside or set-aside and rewetted, i.e. no tax is paid on the remaining emissions. If the landowners have applied to set-aside and rewet the land, but the authorities have assessed that it does not seem possible to rewet the land for practical, economic or legal reasons, it can be considered to waive the tax. Consideration will need to be given to how to identify which land should have the tax waived. As mentioned, the tax and the prospect of a higher tax is intended as an instrument to increase the incentive to allow carbon-rich agricultural land to be taken out of production.

The effect of the recommendations presupposes that a political decision on the adoption of a tax is made as soon as possible in order to provide the necessary administrative basis for a credible prospect that the tax can be raised if the desired set-aside is not achieved.

3.1.4. Prerequisites

Map basis

In 2020, the Ministry of Climate, Energy and Utilities initiated a research project on greenhouse gas emissions from carbon-rich agricultural land based on a report from Aarhus University (AU) that stated that the calculation of emissions from carbon-rich land was subject to considerable uncertainty.

AU pointed out, among other things, that the area of carbon-rich land in the emissions inventory is assumed to remain constant in the period after 2010, despite the fact that agricultural land will degas over time and thus can no longer be classified as carbon-rich (mineralisation). In addition, there is uncertainty about the relationship between carbon content and emissions, and the cultivated carbon-rich agricultural land is generally less drained and thus more water-saturated than assumed in earlier calculations and projections.

The project is divided into two parts. In a first partial delivery published in December 2023, Aarhus University has mapped the distribution of Danish carbon-rich agricultural land, including estimating the mineralisation of carbon-rich agricultural land over time. The second partial delivery concerns the emissions factor from carbon-rich agricultural land, including the relationship between soil carbon content, water levels and emissions. The Ministry of Climate, Energy and Utilities expects to receive the second partial delivery in 2024 for inclusion in *Climate Status and Outlook 2025*. Based on the second partial delivery, emissions and effects must be recalculated.

Based on the new map basis, the area of carbon-rich land in Denmark is estimated to be 218,180 hectares, of which approx. 117,000 hectares are within the agricultural area. This corresponds to 54.2 per cent.

The area of carbon-rich land is mapped by Aarhus University based on a model that uses point measurements of carbon content in around 10,000 sample locations as well as a number of environmental variables. Aarhus University delivered an updated map to the Ministry of Climate, Energy and Utilities in December 2023, based on the collection of 733 new soil samples in 2022.

The map shows the carbon content of Danish land at a resolution of 10x10 metres.

Table 3.2. Distribution of carbon-rich agricultural land, 2022 (hectares)

	Within the agricultural area	Total
6-12 per cent carbon content	71,217	129,234
> 12 per cent carbon content	45,585	88,946
Total	**116,802**	**218,180**

Source: DCE, Scientific note no. 2024 60 based on AU, Peat 2022 map

3.1.5. Current efforts to set-aside and rewet carbon-rich agricultural lands

The Danish Environmental Protection Agency's scheme

The Danish Environmental Protection Agency currently administers a subsidy scheme for the rewetting of carbon-rich agricultural land for the purpose of restoring natural hydrology to achieve a reduction in CO_2-eq emissions while supporting other nature, environmental and climate adaptation considerations. Under this nationally funded scheme, a municipality or a farmer applies for a grant for a feasibility study. Once the feasibility study has been completed, the Danish Environmental Protection Agency decides on the realisation of the project. The Danish Environmental Protection Agency can pay one-off compensation, but land redistribution is not part of the scheme.

The Danish Nature Agency's peatland projects

The Danish Nature Agency has a capital appropriation and is currently working on a number of projects to rewet carbon-rich agricultural lands throughout the country in collaboration with municipalities and agricultural organisations. These nationally funded peatland projects are climate-focused, although it is possible to support other considerations and thus create more holistic projects. In connection with projects, the Danish Nature Agency can allow the farmer to participate in land distribution to promote the realisation of projects, thus providing participating farmers an opportunity to receive land and contiguous areas possible for cultivation. Areas purchased as part of a project is resold after the project has ended in order to reuse the funds for further set-aside of agricultural land. In the event of a sale, easements restricting agricultural use of the property will be registered.

The Danish Agricultural Agency's scheme
The Danish Agricultural Agency currently administers the 'Water and Climate Projects' scheme. The scheme aims to promote the completion of peatland and wetland projects. The peatland projects aim to reduce greenhouse gas emissions from agriculture by extensifying operations and wetland restoration of high-carbon agricultural land. The wetland projects must contribute to reducing the discharge of nitrogen or phosphorus to fjords and coastal waters. A proportion of wetlands overlap with carbon-rich agricultural land, so they can also contribute with climate effects. In this scheme, it is possible to use land distribution and land acquisition as an alternative to compensation.

It is either the municipalities or the local units of the Danish Nature Agency that are granted commitments under the 'Water and Climate Projects' programme to implement either peatland projects or nitrogen wetland projects as part of the implementation of set-aside projects, the municipalities or the Danish Nature Agency enter into agreements on compensation to landowners who allow areas to be included in a set-aside project.

Peatland projects under the Danish Agricultural Agency are financed 100 per cent by the European Common Agricultural Policy (CAP), and nitrogen wetland projects are financed 80 per cent with funds from agricultural subsidies and 20 per cent with national funds.

3.1.6. Cost elements

The socio-economic costs of rewetting carbon-rich agricultural lands are modelled with three cost components, *see Box 3.1*.

Box 3.1

Description of the components of the socio-economic costs

The socio-economic costs are calculated as:

$$\begin{aligned}\boldsymbol{Socio-economic\ costs}\\ &= \boldsymbol{costs\ of\ loss\ of\ cultivation\ value}\\ &+ \boldsymbol{costs\ of\ wetland\ restoration}\ + \boldsymbol{costs\ of\ marginal\ areas}\end{aligned}$$

The socio-economic costs of setting aside and rewetting carbon-rich agricultural land consist of:

- Loss of cultivation value on the carbon-rich land: Income from cultivating the land is determined by the cultivation value. When land is set aside, this revenue is lost. In addition to the actual cultivation value, this item also includes the value of the land as a so-called harmony area, i.e. land that can be used to fulfil other regulations. Finally, this cost component includes compensation to the farmer for time spent on administration etc.

- Costs of wetland restoration (construction etc.): When the land is set aside and rewetted, it is associated with construction costs. In addition, there may be the establishment of preventative measures in the form of dikes/embankments to prevent the wetland from affecting neighbouring infrastructure that is not carbon-rich agricultural land, such as residential areas. It can also be preventative measures to avoid leaching of phosphorus. The cost also includes feasibility studies and any administrative costs related to land consolidation.

- Costs of setting aside peripheral areas: It will often be necessary to rewet organic soils adjacent to the carbon-rich agricultural land (extent will depend, among other things, on preventive measures such as dikes, etc.). In this connection, there are costs for loss of cultivation value and costs for construction etc. for these.

For a given soil, it is the sum of these three components that determines the total cost of rewetting. Each of the three components is subject to significant variation, and therefore the cost of taking out agricultural land varies greatly; the more land you want to set aside, the less likely you are to opt out of difficult and costly projects. Therefore, increased set-aside is likely to result in increased costs.

At a level of ambition of 70,000 hectares, the average total cost to the state is estimated at DKK 239,000 per hectare of carbon-rich agricultural land If this cost is spread over all the hectares that are expected to be included in the projects – i.e. including peripheral areas – the cost is estimated at DKK 119,000 per hectare. These cost estimates assume that the introduction of a tax will reduce compensation rates. It should be noted that a higher price per hectare has been used in the preliminary assumptions for *Climate Status and Outlook 2024*.

The selection of projects depends partly on the willingness of landowners and partly on the cost-effectiveness of the projects. This means that the cheapest land is preferably selected, but the fund that can be selected from does not include all land.

Lost cultivation value and compensation

According to current rules, the land can basically receive the same basic payment per hectare from the common agricultural policy both before and after removal and wetland restoration.[19] Thus, as a starting point, the loss of the hectare subsidy for the set-aside of carbon-rich agricultural land should not be considered.

The cultivation value associated with a given piece of land depends to a large extent on the type of farming that takes place on the land. This is currently taken into account when it comes to determining the current compensation rates, which are the basis for the calculation of the level of compensation Thus, the compensation that the farmer receives today varies from just under DKK 5,000 per hectare for natural areas to over DKK 80,000 per hectare for crop rotation land. Permanent grazing land is associated with a compensation rate of approx. DKK 36,000 per hectare. In addition to lost cultivation value, the compensation also covers the value of lost harmony area and one-off administration costs.

Costs of wetland restoration

The peatland projects that have received commitments in the period 2020-2022 are used to estimate the costs of wetland restoration. Data from this period, along with

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[19] For EU-funded projects that only have a climate impact and do not contribute to directive implementation, the possibility of basic payment is limited to a maximum of five years.

assessments from relevant agencies, are used to construct a cost curve for wetland restoration.

The cost of wetland restoration varies considerably from land to land. Often, construction costs will be lower on peripheral areas than on carbon-rich land It is estimated that the average cost for wetland restoration at the set level of ambition amounts to DKK 78,000 per hectare when the peripheral area is taken into account.

Peripheral areas

Typically, the wetland restoration of carbon-rich land will involve the rewetting of neighbouring areas without high carbon content. This ensures a more natural demarcation of the project area and can minimise the need for costly measures such as dikes and pumps. The most cost-effective projects will usually take place in areas that are naturally bounded by carbon-rich soils and thus require only a modest amount of peripheral area. As the extent of setting aside increases, it will be necessary to implement projects on carbon-rich agricultural land, which is more difficult to delineate and thus requires more peripheral area. Especially the so-called fragmented carbon-rich land – i.e. small isolated blobs on the map – can require significant peripheral land.

It is assumed – in accordance with the preliminary assumptions behind the *Climate Status and Outlook 2024* – that on average 1 hectare of peripheral area is taken out for every hectare of carbon-rich agricultural land. Thus, the total project area will be 140,000 hectares. However, part of this area is already out of agricultural use. The area taken out of agricultural use is estimated to be approx. 110,000 hectares, which, in terms of size, corresponds to almost the entire island of Lolland.

3.1.7. Impact on nature and the environment

Nitrogen

As shown in the section above, the current 'Water and Climate Projects' scheme aims to finance both peatland projects (primarily for climate purposes) and wetland projects (primarily for nitrogen purposes). If a credible threat of a higher tax on carbon-rich agricultural land is implemented, it could have a positive knock-on effect on the realisation of wetland projects. This is because it is assumed that a proportion of the wetlands are located on carbon-rich agricultural land.

Based on the assumptions behind the *Agreement on the Green Transformation of Danish Agriculture*, it is expected that the setting aside and rewetting of carbon-rich agricultural land will reduce the nitrogen load in coastal waters by approx. 40 kg nitrogen per hectare of project area per year.

Nature and biodiversity

The set aside of carbon-rich agricultural land can also contribute to more and better nature on land and increase the diversity of plant and animal species on the land. In the long term, the rewetting of carbon-rich agricultural land can thus contribute to improving nature and increasing biodiversity in Denmark, both on land and at sea.

The wetland nature that exists or can be restored on carbon-rich agricultural land is mainly swamp forests, bogs and meadows. These are areas that can develop into natural areas with protected habitats (also referred to as § 3 areas) and that can be important habitats for many wild animals and plants. Birds and amphibians in particular, including particularly vulnerable, threatened or protected species, will be able to utilise the areas as habitats.

Further potential for enhancing nature and biodiversity exists through the set-aside of carbon-rich agricultural land surrounding existing natural areas. If such carbon-rich agricultural land is set aside, it can act as a buffer between natural areas and intensively cultivated land by reducing the nutrient impact on existing natural areas, thereby improving existing nature and biodiversity. Irrigation of carbon-rich agricultural land around and between natural areas such as meadows and marshes is expected to develop into habitats for species and nature over time, thus creating more and coherent nature and contributing positively to the quality of nature.

3.1.8. Bottlenecks for set-aside

The technical estimate assumes that any bottlenecks in the set-aside effort can be handled. Based on experience from the current set-aside schemes, the Danish Agricultural Agency has identified potential bottlenecks for the fulfilment of the technical estimate, which are described below. These bottlenecks and the amount of resources allocated to deal with them can thus have an impact on the rate of set-aside and thus the effect in 2030.

Project management

Very few projects can be established by individual farmers, as the areas to be wetted typically are owned by more than one farmer. Today, this role is performed by the municipalities or local departments of the Danish Nature Agency, with a few exceptions, depending on the project organisation. If there is a shortage of qualified personnel at the Danish Nature Agency and the municipalities, it can create a risk that projects are not initiated or delayed in their implementation, or not applied for in the first place.

Technical feasibility study

Prior to a wetting project, it must be ensured, among other things, that there is complete clarity about which areas will be wetted in the project. This may involve flooding of areas other than agricultural land, such as housing, infrastructure, etc. Today, feasibility studies are primarily carried out by consultancy companies such as WSP, COWI, SWECO and Envidan, which are hired for the task by municipalities and the Danish Nature Agency Increased set-aside will, therefore, lead to an increased need for consultancy services for technical feasibility studies.

Land distribution and purchase/sale

Land distribution and purchase/sale is an important element of the Danish Nature Agency and the Danish Agricultural Agency's current rewetting projects. In a land distribution, the landowner can choose to sell their land or to receive compensation for the restrictions on availability that the project entails If desired by the landowner, replacement land can be purchased in connection with land distribution for the project land that is to be taken out of rotation, so that an area for e.g. feed production and spreading of the property's livestock manure can be maintained. At the same time, better consolidation of the property's areas can be created, which typically leads to operational and socio-economic benefits. An increased set-aside will lead to an increased need for land distribution and purchase/sale, which is dependent on qualified land distributors and a land distribution commission to approve the land distribution at a land approval meeting, surveyors to determine the project boundary and new boundaries, land registration, etc.

Permits from the authorities

When agricultural land is rewetted, a number of different permits are required. Municipalities are the primary authority on the most commonly occurring ones. Examples include screening in accordance with the Environmental Assessment Act, exemptions/permits under Section 3 of the Nature Conservation Act, watercourse permits and rural zone permits.

State authorities also often need to issue regulatory decisions in order for projects to be realised. Examples include the Danish Coastal Directorate (dune and beach protection), the Conservation Board (conservation areas), the Danish Agency for Culture and Palaces (dykes and ancient monuments), the Danish Environmental Protection Agency (Forestry Act), the Danish Road Directorate (Road Act) and the Danish Agricultural Agency (Agricultural Act). In state-owned projects (by the Danish Nature Agency), the Danish Environmental Protection Agency is the environmental assessment authority and is responsible for screening and any environmental impact assessment (EIA).

Contractors

Contractors usually establish set-aside projects, which is why an increased set-aside effort will lead to an increased demand for contractors. In addition, construction work for peatland projects should preferably take place during the dry months, as driving in peatland areas is often impossible or significantly more difficult in wetter conditions.

Administration and processing of subsidies

The case processing of peatland projects is demanding, with many assessments and calculations as well as diverse functions. It requires a long training programme for administrators. An increased set-aside effort will mean that administration capacity must be built up in time.

The Danish Environment and Food Board of Appeal and the Danish Town and Country Planning Board of Appeal

Most regulatory decisions that are prerequisites for realising a project involving the set-aside of carbon-rich agricultural land can be appealed to the Danish Environment and Food Board of Appeal and the Danish Town and Country Planning Board of Appeal. Appeals against regulatory decisions, which are a prerequisite for the realisation of the projects, can, if they have a suspensive effect, significantly postpone the projects and thus delay the overall effort.

3.2 Regulation of Fertiliser

In the following, the Expert Group's considerations on the regulation of fertilisers are presented, either through a fertiliser tax with a base deduction or by restructuring direct agricultural subsidies into subsidies for reduced fertiliser usage

CO_2-eq emissions related to fertiliser applied to fields are expected to amount to a net 1.7 m tonnes of CO_2-eq in 2030, *see Climate Status and Outlook 2021*. Add to this 0.2 m tonnes of CO_2-eq from liming.

This chapter elaborates on fertiliser regulation and how it relates to existing nitrogen regulation. The Expert Group has analysed two different regulatory models for fertilisers, which weigh the considerations of the Danish Climate Act and the terms of reference for the Expert Group's work in different ways. The Expert Group has analysed the following two regulatory approaches;

a. A tax on fertiliser usage of DKK 750 per tonne of CO_2-eq and a base deduction corresponding to 50 per cent of the tax base, paid per hectare of agricultural land
b. Restructuring of the direct agricultural subsidy to a subsidy for reduced fertiliser usage of DKK 750 per tonne of CO_2-eq.

Both regulation models involve a tax on applied agricultural lime corresponding to DKK 750 per tonne of CO_2-eq.

Table 3.3 provides an overview of the climate effects, shadow prices and burden on business of the two regulatory models. CO_2-eq reductions from fertiliser regulation can be split into a direct effect due to reduced fertiliser usage on the fields and an indirect effect through changed production behaviour in agriculture and the rest of the economy as a result of fertiliser regulation. In the table, interaction effects show that reductions in emissions largely depend on how livestock production responds to a new regulation of fertiliser usage.

Table 3.3. Effects of variant a and b for regulating CO2-eq emissions from applied fertiliser.

	Variant a Tax and base deductions	Variant b Subsidy
Tax/subsidy rate, DKK per tonne	750	750
Net reduction of emissions in 2030, m tonnes of CO_2-eq	0.28	0.09
- of which interaction effect between tax on livestock and tax on fertiliser[1)]	0.16	-0.03
Shadow price[2)], *DKK per tonne of CO_2-eq* (excl. side effects and terms of trade effects)	190	380
Shadow price[2)], *DKK per tonne of CO_2-eq* incl. side effects (excl. terms of trade effects)	-490	380
Burden on business, *DKK m*	200	175
Total decline in land values from fertiliser regulation excluding forest, *per cent.*	-1.1	1.1

Note: 1) In model a, interaction effects will lead to additionalCO2-eq reductions, which covers the fact that animal production is reduced by a fertiliser tax, as the cost of roughage for the animals increases. In model b, the interaction effects will conversely reduce the total CO2-eq reductions, as subsidies for reduced fertiliser usage increase the yield of marginal land to the extent that the cost of reducing fertiliser use is less than the subsidy. This reduces the cost of roughage slightly and thus increases animal production.

2) It should be noted that the shadow price is calculated including interaction effects, i.e. that part of the effect comes from the interaction between the regulation of fertiliser and a possible tax on livestock etc. in the primary models.

Source: Own calculations based on calculation from Ørum, J. E. (2023), Department of Food and Resource Economics, unpublished working paper delivered to the Ministry of Food, Agriculture and Fisheries, December 2023.

Climate regulation of fertiliser applied on the field

The Expert Group has looked at the possibilities of regulating agricultural emissions of greenhouse gases (nitrous oxide from nitrogen) from fertiliser usage via a tax on the total amount of fertiliser applied (variant a) or by restructuring the direct agricultural support to subsidies for reduced fertiliser usage relative to the applicable nitrogen norm[20], which sets a ceiling for the use of nitrogen in fertiliser based on the specific crop and soil type (variant b). The reduction is then deducted from the farm's total nitrogen quota. Increased regulation of fertiliser use by farmers will lead to reduced yields, whether through a tax or through subsidies for reduced fertiliser usage.

Reduced fertiliser usage on the field will impact several emission categories in the national emissions inventory. The dominant effect will be a reduction in direct nitrous oxide emissions from nitrogen in fertiliser applied to the field, and thus in net CO_2-eq emissions. There will also be a reduction in indirect nitrous oxide emissions as well as reduced carbon storage in mineral soils, as less organic matter is added to the soil through fertiliser and plant cover.

Climate regulation of lime applied to the field

Agricultural lime is applied to certain Danish agricultural land to optimise the soil's pH and thus the availability of certain nutrients for plants (including nitrogen) and on difficult clay soils to improve the soil structure and thus cultivability. The use of agricultural lime emits CO_2-eq as a result of the chemical reactions that occur during the dissolution of the applied material. The application of lime on fields is not currently regulated.

It should be noted that with a tax on the use of agricultural lime, and thus an expected reduction in the use of agricultural lime, there is a risk of acidification of the cultivation soil, which can lead to less effective nitrogen uptake in the crop. The consequence of this will be lower yields or an increased need for nitrogen input, resulting in increased emissions from fertilisers. Recent research also shows that liming acidic soils can have a reducing effect on the amount of nitrous oxide emitted from the soil as a result of nitrogen decomposition.[21] However, this interaction between direct CO_2-eq emissions and nitrous oxide emissions from soils is not currently reflected in the national calculation method.

3.2.1. Advantages and disadvantages of fertiliser regulation

Tax on fertiliser with base deduction

A uniform tax system on applied fertiliser puts a uniform price on the CO_2-eq emissions that occur when fertiliser is applied to fields, regardless of crop choice. The

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[20] *Box 3.8*, in the section on implementing fertiliser subsidies, describes the setting of nitrogen norms in more detail.

[21] https://agro.au.dk/aktuelt/nyheder/vis/artikel/kalkning-af-sur-jord-reducerer-udledning-af-lattergas-og-oeger-udbyttet

tax on fertiliser use will thus provide an incentive to reduce fertiliser usage within existing field operations and increase the incentive to shift field operations towards crops with a lower fertiliser requirement and permanent set-aside of agricultural land. A tax on applied fertiliser is thus assessed to be the most socio-economically cost-effective instrument for achieving CO_2-eq reductions, as the tax provides a uniform incentive for CO_2-eq reduction across the instruments. A tax on fertiliser usage also provides an incentive to shift production to less climate-intensive production, such as forestry.

If the tax in practice drives activity shifts between crops, this will reduce the structural effect of the tax and increase the technical and other effects. The size of this effect is unclear.

A base deduction in the fertiliser tax is based on the number of hectares in a farm. The combination of a higher marginal tax rate and a base deduction means that the marginal tax determines the farmer's incentive to lower their fertiliser usage, while the base deduction per hectare is fully capitalised in the land value and, therefore, mitigates the land price loss from the tax on fertiliser usage. The base deduction thus reduces the burden on business.

If a fertiliser tax is introduced without a base deduction, it will lead to a greater loss in land value. For this reason, a tax model with a base deduction favours existing farmers by directly compensating for part of the loss in land value.

It should be noted that if the tax is phased in from 2027, the tax will immediately lead to a need to adjust current CAP subsidy schemes for 2027, such as the organic subsidy and the targeted nitrogen regulation. This should be seen in light of the fact that EU state aid rules dictate that, as a starting point, you may only compensate for the costs of the programme in question. An increase in the tax will thus be offset by a reduction in the subsidy.[22]

A restructuring of the direct agricultural subsidy to subsidies for reduced fertiliser usage

A restructuring from direct agricultural subsidy to subsidies for reduced fertiliser usage provides an incentive for a reduction within existing field operations, but unlike a tax, there is no increased cost for the remaining fertiliser usage. This reduces the structural effect in comparison to the tax model and thus the risk of carbon leakage.

It is expected that a restructuring of the direct agricultural subsidy to subsidies for reduced fertiliser usage could be implemented based on the existing targeted regulation, *see Chapter 5*. However, it must be assessed whether organic farms can receive both organic area grants and subsidies under the scheme.

The subsidy for reduced fertiliser usage is assumed to be financed by a reduction in the direct agricultural subsidies that farmers receive based on their land area. The existing hectare subsidy is given per hectare regardless of whether the land is cultivated or fallow.[23] Although direct agricultural subsidies do not distort production

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[22] The subsidy schemes compensate the farmer for the costs and lost income that participation in the scheme entails. A fertiliser tax will certainly affect the contribution margin when cultivating the land and thus the need for compensation for loss of income due to changes in operation as a result of participation in the subsidy scheme.

[23] Farmers must fulfil a number of conditionality requirements regarding the climate and environment, public and plant health and animal welfare in order to be eligible to receive hectare subsidy.

within agriculture, direct agricultural subsidies can be considered a distortion across the entire economy, as the hectare subsidy creates an incentive to maintain agricultural production over other land uses. In addition, the hectare subsidy is a redistribution to agricultural land owners from the rest of society. The direct agricultural subsidies also tie up public funds that could have been used for e.g. CO_2-eq-reducing technologies.

The hectare subsidy will be reduced for all farmers, regardless of whether they receive a subsidy for reduced fertiliser usage or not. This means that ecologists, for example, can help finance the restructuring of the direct agricultural subsidy. If they can't receive the subsidy, it will reduce the incentive for organic farming, all other things being equal. However, the effects of reduced direct agricultural subsidies are expected to be partially offset by increasing subsidies for organic farming. Thus, there is an opportunity to increase the current subsidy levels for organic farming within the subsidy ceilings calculated on the basis of Pedersen (2020).[24] The consequences and effects of this need to be investigated further.

As the model is financed through a restructuring of the direct agricultural subsidy, there will be no additional revenue, unlike the tax model, and thus no revenue to be returned to the industry.

Since the model is financed by the direct agricultural subsidy, the overall regulation implies a decline in land values. The positive effect of the subsidy on land value is more than offset by the reduction in direct agricultural subsidies, which capitalises into lower land values. According to the GreenREFORM model, the decline in land value will be slightly larger in the subsidy model than in the tax model with a base deduction. However, the calculated difference in the effect on the land values depends on the specific assumptions about substitution between crops and the effect on cultivation intensity of a tax versus restructuring of the direct agricultural subsidy, and the expert group assesses that there is hardly any significant difference in the land value effect in the two regulatory models. Furthermore, unlike the tax, the subsidy relieves the effect on the farmer's contribution margin, as no tax is paid on the fertiliser that continues to be used.

The tax with base deduction leads to higher operating costs and increased structural effect, but also slightly higher value of the production land than the subsidy model. Part of the subsidy for fertiliser reduction will also be capitalised into the price of land, but as the subsidy is conditional on the land not being taken out of use, less land is set aside, which in isolation lowers the land values. Further, a share of the savings from the subsidy is shared with consumers through a lower increase in food prices, which lowers the structural effect relative to the tax model.

A subsidy for reduced fertiliser usage is determined based on the applicable nitrogen norms, which set a ceiling for nitrogen use when growing a given crop on a given soil type. As the nitrogen norms are set per crop, there is no incentive to switch to less fertiliser-intensive crops, which may reduce the emission reduction compared to the tax model.

The nitrogen norms are set on the basis of the average economically optimal use of nitrogen across farm types, *see Chapter 5*. In practice, the economically optimal

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[24] Pedersen, M. F., (2020). Background calculations for the determination of subsidy rates for organic area subsidy in CAP 2020, 36 p., IFRO Commissioned Work No. 2020/06.

use of nitrogen will vary between farms. In this way, the subsidy risks being paid out without leading to a real change in the behaviour of farmers whose optimal and actual nitrogen use is lower than the nitrogen norm. In practice, however, this only has a distributional impact.

3.3 Forest

The total carbon stock in Danish forests in 2022 was approx. 160 m tonnes of carbon, corresponding to approx. 600 m tonnes of CO_2. Since 1990, Danish forests have increased their carbon storage in the living biomass (trunks, branches, leaves, needles and roots) by 16.2 m tonnes of carbon. This means that forests have removed over 59 m tonnes of CO_2 from the atmosphere, or about 1.9 m tonnes of CO_2 per year. The net uptake is both due to the fact that the forest area has increased since 1990 and that the old forests have become denser or richer in wood mass[25], since annual growth rates in forests have exceeded the amount of logging.[26]

Since 1990, the Danish forest area has expanded by approx. 3,000 hectares per year. During this period, afforestation has been promoted through state afforestation, subsidies for private afforestation and, most recently, through the Danish Climate Forest Foundation.

Afforestation is a socio-economically appropriate climate initiative that contributes to CO_2 reductions in the long term. This is partly due to high climate effects in the period 2035-2050 and the high co-benefits associated with forests, such as recreational values and reduction of nitrogen leaching. As a result, afforestation is a key transitional element to fulfil climate targets beyond 2030.

Afforestation has a limited short-term climate impact. This is mainly due to the fact that newly planted forests' growth and thus CO_2 uptake is relatively low in the first years after planting. Forests typically reach a peak of growth around the age of 20-40 years or more. When national forests are used for wood products, they contribute to temporary carbon storage in the harvested wood products category according to the IPCC guidelines, from which CO_2 is continuously depreciated in the inventory as wood products decay or burn.

3.3.1 Recommendations regarding forests

In the Expert Group's models, the subsidy for afforestation is increased to incentivise the establishment of 250,000 hectares of new forest by 2045, when Denmark aims to be climate neutral.

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[25] The wood mass of the forest is the above-ground living biomass in the form of trunks and branches.

[26] Logging is when the trees are felled and trunks and larger branches are typically sold as, for example, timber and wood biomass, while roots, leaves, needles and smaller branches are often left in the forest.

3.3.2. Subsidy for afforestation

The Expert Group's models include the establishment of a subsidy scheme for private afforestation of almost DKK 92,000 per hectare, which is more than double the current DKK 35,000 per hectare for the current subsidy for private afforestation financed by agricultural subsidies. It is estimated that the subsidy can be increased, as it is possible to compensate for lost income from agricultural operations when converting to forestry. In the current subsidy scheme, subsidies are given for establishment and maintenance in the first year, subtracted with income from logging, with no subsidies given for lost income.

The subsidy rate thus includes costs associated with planting material, establishment of the forest subtracted with current income from the sale of wood of approx. DKK 20,000 per hectare. Compensation for operation and maintenance of approx. DKK 24,000 per hectare. In addition, the marginal opportunity cost associated with agricultural operations based on the price projections used in the tax modelling calculations of approx. DKK 48,000 per hectare

A subsidy for afforestation of just under DKK 92,000 per hectare is estimated to increase afforestation up to and including 2030 by 50,000 hectares of new forest, and increase afforestation up to 2045 by a further 200,000 hectares of new forest. By 2045, a total afforestation of 250,000 hectares will be achieved in addition to the expected afforestation in the *Climate Status and Outlook 2023*. Realising afforestation on this scale is associated with uncertainty. In the short term, there may be limited availability of planting material of the right type and quality, which may limit annual planting up to 2030.

The subsidy is assumed to be implemented from 2025 and is estimated to have a CO_2 effect (uptake) of 0.1 m tonnes of CO_2 in 2030, 0.7 m tonnes of CO_2 in 2035 and 2.1 m tonnes of CO_2 in 2045, *see Table 3.4*. The subsidy of approx. DKK 92,000 per hectare corresponds to a cost of approx. DKK 470 per tonne of absorbed CO_2 with a socio-economic shadow price of approx. DKK -400 per tonne, where positive side effects are taken into account in the form of less nitrogen discharge to the aquatic environment as well as recreational value.

In addition to the CO_2 effect in the LULUCF sector, which includes the CO_2 uptake in the trees themselves, the forest floor and the soil, there is a CO_2-eq effect in the agricultural sector of 0.05 m tonnes of CO_2-eq in 2030 as a result of agricultural land being taken out of operation and fertilisers no longer being applied. There will be overlap between this effect and a CO_2-eq tax on agriculture, which will also lead to the set-aside of land. The total effect for fertilisers can be found in *Chapter 2*. In addition, there will be derived CO_2 effects on energy consumption from converting agricultural land to forest, which are not included in the current calculations.

Table 3.4. Afforestation and CO_2-eq effects and side effects

Total afforestation in addition to KF23			**CO_2-eq effect, 2030**			**CO_2-eq effect 2035**	**CO_2-eq effect 2045**	**Shadow price excl. side effects**	**Shadow price incl. side effects**	**Subsidy rate**
Thousand hectares	Of which 2025-2030	Of which 2030-2045	m tonnes of CO_2	Of which LULUCF	Of which agriculture	m tonnes of CO_2	m tonnes of CO_2	DKK per tonne of CO_2	DKK per tonne of CO_2	DKK per hectare present value
250	50	200	0.15	0.10	0.05	0.67	2.10	470	-400	92,000

Note: Figures are rounded. Costs and shadow price are in 2023 factor prices. The stated 250,000 hectares of afforestation and its CO_2-eq effects are beyond what is already expected with KF23. It is assumed that the first forest planting will take place in 2025. The calculations assume that the forest is planted on mineral soil and that there is then increased carbon sequestration in the soil compared to continued farming. If the forest is planted on carbon-rich drained land, there will still be emissions associated with the soil. Side effects include less nitrogen discharge to the aquatic environment and recreational value of forests.
Source: IFRO Commissioned Work 21/09, IFRO Commissioned Work 2022/04, IGN and own calculations

In the Expert Group's model, forests are planted with tree species that strive for high CO_2 uptake in both the short and long term, including by mixing fast-growing tree species, while at the same time focusing on ensuring robust and stable forests that are resilient to the climate of the future and that also have the potential to harvest synergy effects in relation to other purposes. Specifically, the calculations are based on forest mixes consisting of 50 per cent traditional tree species mix (afforestation since 1990) with predominantly deciduous trees and 50 per cent fast-growing trees, including a large proportion of conifers. The forest is predominantly assumed to be managed as a production forest, i.e. the trees are continuously harvested and sold for timber or energy wood. When it comes to actual implementation, there should be a focus on involving local stakeholders so that the forest is placed with the greatest possible value for the surrounding community, and there is interaction with other land use initiatives, such as the set-aside of carbon-rich agricultural land.

Financing of afforestation and realisation

The Expert Group assumes that afforestation will be financed by national funds, where a national afforestation scheme must be established as soon as possible under the Ministry of the Environment, through which the afforestation effort can be managed. The introduction of a more favourable national scheme is assumed to mean that the current CAP scheme will not be applied for. Specifically, this will mean that approx. 70 m annually from 2025-2030 from the CAP scheme for afforestation, with an expected realisation of almost 14,000 hectares in the same period, will have to be reprioritised. The announcement of a higher subsidy rate may also lead to the cancellation of applications under the Rural Development Programme (RDP) in 2023. Implementation will also depend on when a decision is made to increase the subsidy.

The total costs associated with subsidies for afforestation up to 2045 are estimated to be around DKK 20 bn, *see Table 3.5*. The total costs include the financing of the almost 14,000 hectares of forest that are no longer realised through the agricultural subsidy for forests, which means that a total of 264,000 hectares of forest are financed. In addition, other afforestation from already allocated finance act funds is assumed to be unaffected, *see memorandum outlining preconditions for Climate Projection 2023.* However, the efforts under the Danish Climate Forest Foundation may need to be adapted in relation to a new subsidy scheme so that the schemes support each other.

Table 3.5. Costs associated with afforestation

Expenses, DKK m	2025	2026	2027	2028	2029	2030	Total, 2025-2045
Start-up aid	189	189	189	209	229	235	5,222
Care, upscaling of plant material	46	92	138	188	244	255	5,710
Loss of income*	38	76	115	157	203	249	9,134
Total expenses	274	358	442	555	676	739	20,066

Notes: Costs are in 2023 factor prices.
*Loss of income covers both lost contribution margin and loss of potential future income associated with other land use, as well as potential future loss of the hectare subsidy.
Source: Own calculations

Realising afforestation on this scale at the calculated subsidy rate will depend, among other things, on future prices for agricultural operations, wood products and prices associated with alternative use of land, such as buildings and renewable energy production. By combining subsidies with a requirement for a duty of forest preservation, it can be ensured that the operation of the forest is regulated by the Forestry Act. To ensure sufficient afforestation, the subsidy rate is continuously evaluated in relation to other land uses so that, if necessary, afforestation can be stimulated in other ways, e.g. by allocating more funds to state afforestation or by increasing incentives to plant new private forests.

To ensure that the conversion to a forest is permanent, the subsidy can be conditional on the areas being subject to a duty to preserve a forest, possibly with the possibility of a temporary right of cancellation against repayment of the subsidy if the duty of forest preservation is perceived as a barrier to afforestation with a subsidy.

Synergies from afforestation
Newly established forests can have a number of side effects/externalities, such as impact on the aquatic environment, recreational value, biodiversity, health, etc. Efforts should be made to promote these synergies.

The shadow price calculation in *Table 3.4* includes the recreational value of forests and the value of reducing nitrogen emissions, *see Appendix 7.9*. Set-aside of agricultural land for forestry will have value in areas with a need for action in the water plans due to reduced fertiliser use and the forest retaining nitrogen. An average value of nitrogen emissions has been used, *see Appendix 7.9*, as the location of the forest is not known in advance. Afforestation in isolation does not have an effect on ammonia emissions, but the reduced fertiliser use on agricultural land reduces ammonia emissions. The socio-economic value of this is calculated for the total change in fertiliser use and is shown in *Table 3.4*. Therefore, this value is not included in the calculation of the shadow price of afforestation.

The location, layout and access conditions are of great importance for the use of the forest, and thus the recreational value. Many new public forests are located close to the city, and there is free public access everywhere in the forests at all times. In private forests, access is restricted to roads and paths and only during daylight hours. These differences may have contributed to the fact that in a 2014 report, the Danish Economic Councils estimated the recreational value of state afforestation to be approx. DKK 50,000 per hectare per year in 2023 prices, while the corresponding value for private afforestation was estimated to be DKK 4,000 per hectare per year.

This report is based on private afforestation and therefore uses a value of approx. DKK 4,000 per hectare per year. Assessing the recreational value is associated with particular uncertainty, as the specific design of the forests is not known, and a significant expansion of the forest area can affect the marginal recreational value of forests. The recreational value can also change over time as the forest grows.

The Expert Group has presented a model with private afforestation, as this results in the lowest public costs (per tonne of CO_2-eq). However, the high recreational value of state afforestation may mean that more funds should be allocated to achieve the same CO_2-eq effect with higher state costs but greater recreational value. The Expert Group's models therefore imply that the relevant authorities and political decision-makers ensure an appropriate distribution of private and state-owned forests based on an overall assessment of costs and socio-economic profitability, including consideration of the applicable environmental and nature objectives.

3.3.3 The framework for forest regulation

Private afforestation is subsidised under the Common Agricultural Policy (CAP). Support for private afforestation is in 2023 funded under the Rural Development Programme (RDP) and from 2024 will be funded under the CAP plan, which is part of the Agricultural Agreement. The current subsidy scheme provides start-up aid (and care in the first year), which is deducted from logging revenues.

Afforestation is also supported through the Danish Climate Forest Foundation, where the state on several occasions has contributed funds that can be used for this purpose, along with expected additional funds from private sources. The fund was established in 2020.

In addition, afforestation is supported with funds for state afforestation, which is realised through state purchase of agricultural land followed by planting and state management of the areas. State afforestation is carried out in co-operation with municipalities and waterworks, which co-finance the efforts as a means of ensuring drinking water protection.

Forest management of a given forest area in Denmark is primarily regulated by the Forestry Act. The purpose of the law is to preserve and protect the country's forests and to increase the forest area. The law regulates the use of areas subject to the duty of forest preservation, which covers approx. 70 per cent of the Danish forest area. The main rule is that areas subject to the duty of forest preservation must be kept covered with trees that form or will form a closed forest of tall standard trees.[27] Logging, with the exception of thinning, may not take place until the stand or individual tree has reached an age or dimension where it is ready for logging.

Certain habitats and species that may occur in forests may be protected either by national rules or by rules in the EU nature conservation directives, which are implemented in various national laws.

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[27] Exceptions to the main rule include, among other things, that 10 per cent of the area subject to the duty of forest preservation can be used for logging or wood pasture, another 10 per cent can be used for open nature areas, and 10 per cent can be cultivated with Christmas trees and ornamental greenery.

Other laws and regulations affect forest management more indirectly. This includes the recently adopted EU Deforestation Regulation, which prohibits the sale of a number of products from seven commodity groups, including wood, if they are produced on land that has been subject to deforestation or forest degradation. The regulation will thereby significantly reduce the incentive to clear or degrade forests in Denmark, regardless of whether the area is subject to a duty of forest preservation or not. In addition, the EU Directive on the Promotion of Renewable Energy applies, which lays down rules for the utilisation of forest biomass for energy purposes, including requirements for reforestation of forest areas after logging. The rules apply regardless of whether the forest area is a subject to a duty of forest preservation or not.

3.3.4 Follow the development of existing forests

Current forest projections predict an increase in logging by 2030 and a significant decrease in net forest removals compared to the average of almost 3 m tonnes of CO_2 per year observed over the past 10+ years. The Expert Group has noted that in previous years, significant decreases in net forest uptake have also been projected without subsequently being registered in the actual measured and reported uptake and emissions from forests, *see Section 2.8*. The Expert Group also notes that forest projections are subject to great uncertainty and that they seem to have tended to underestimate the net uptake of forests. The Expert Group is not in a position to assess the reasons for this.

Despite the uncertainties in the projections, the Expert Group assesses that, if desired, the net uptake of forests could be affected temporarily and significantly in the short term by any regulation that limits logging.

Increased net removals in 2030 can be achieved through general reductions in logging, or by introducing more specific regulations that can limit the extent of main logging in existing forests. The Expert Group's models therefore imply that the development in carbon uptake of forests is monitored, but do not recommend specific regulation.

3.4 Handling of Road Transport and Minor Emission Sources

In the following, the Expert Group's recommendations for road transport and minor emission sources are reviewed.

Road transport

Projections show that emissions from road transport will be around 9.6 m tonnes in 2030 if no new initiatives are implemented to reduce emissions. This corresponds to approx. 36 per cent of the expected total Danish greenhouse gas emissions in 2030.

As mentioned in the first interim report, CO_2 reductions through increases in taxes on fuels for road transport in general are significantly more expensive from a socio-economic perspective than in other sectors. This is partly because overall taxes on passenger cars are already very high compared to other areas, and fuel sales are sensitive to cross-border trade. A strict requirement for harmonisation would immediately mean that the tax level on road transport would have to be reduced.

After the transition to a higher and more uniform CO_2 tax in the *Agreement on Green Tax Reform for industry etc.* (June 2022), the total tax level will continue to be higher for motor fuels for road transport than for other applications. In addition, a new CO_2-emissions trading system will be implemented in 2027 that includes fuels for transport, which increases the price of motor fuels. The Expert Group has also noted that sales of green cars have increased significantly in recent years. Furthermore, a road tax for lorries for freight transport has been adopted, which is kilometre-based and CO_2-differentiated according to the lorries' emissions, and will come into force from 1 January 2025.

Finally, the government has proposed increasing the diesel tax by almost DKK 0.50 per litre (2023 prices). This corresponds to an increase of approx. DKK 175 per tonne of CO_2 to a total of approx. DKK 1,575 per tonne of CO_2-eq (2023 prices).

An increase in the diesel tax will increase the tax differential between diesel and other uses, *see Figure 3.1*. Assuming the increase in the diesel tax is implemented – and in the context of the other factors above – the Expert Group has no further suggestions for models for changing the taxes on fuel for road transport.

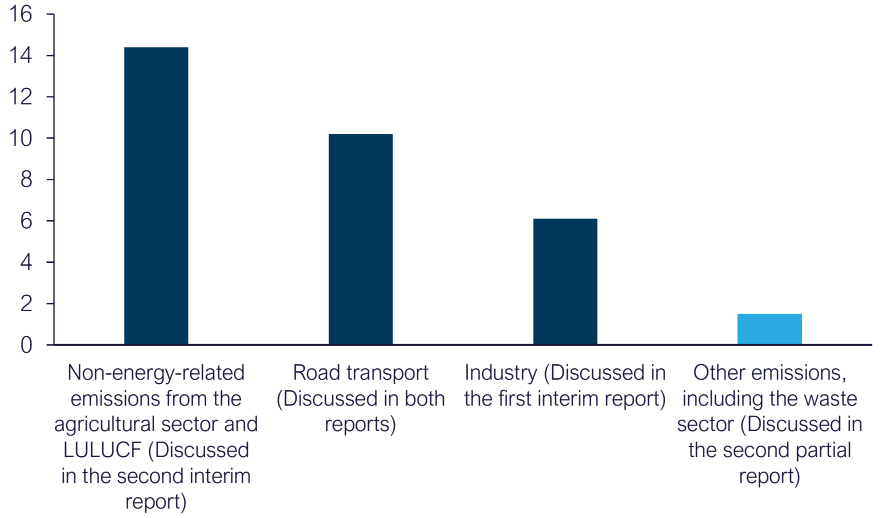
Recommendations for minor emission sources

Minor emission sources cover the categories (CO_2-eq emissions in 2030):

1. F-gases (0.2 m tonnes)
2. Biogas leakage (0.3 m tonnes)
3. Landfills (0.3 m tonnes)
4. Garden and park waste (0.2 m tonnes)
5. Wastewater (0.2 m tonnes)
6. Other, e.g. accidental fires and non-sectoral methane and nitrous oxide emissions from burning biomass (0.3 m tonnes)

Emissions are expected to total around 1.5 m tonnes of CO_2-eq in 2030, *see Figure 3.1*.

Figure 3.1. Expected emissions in 2030, m tonnes of CO_2-eq



Source: Climate Status and Outlook 2023

The Expert Group's models include raising the current tax on F-gases to DKK 750 per tonne of CO_2-eq, corresponding to the tax that was agreed upon for the companies in the industry not subject to ETS. This results in CO_2-eq reductions of 0.1 m tonnes of CO_2-eq in 2030. For the remaining categories, various forms of regulation are already politically planned, which will mean that only very small additional reductions can be achieved through additional tax regulation, which is not considered to be commensurate with the administrative costs of a CO_2-eq tax. In these areas, the Expert Group, therefore, recommends not imposing a CO_2-eq tax but instead implementing the already planned regulatory measures.

F-gases

Part of the Expert Group's models include increasing the tax on emissions of F-gases so that the tax follows the CO_2-eq tax agreed as part of the *Agreement on Green Tax Reform for Industry, etc*. (S, V, SF, RV and K). This maintains the current symmetry where the tax on F-gases is balanced with the current CO_2-eq tax.

In particular, the F-gases HFC and SF6 are emitted in Denmark. HFCs (Hydrofluorocarbons) are mainly used as refrigerants, with the most commonly used F-gases being between 1,000-4,000 times more harmful to the climate than CO_2. HFC is mainly used as a refrigerant in e.g. air conditioning, refrigeration systems and heat pumps. There are no F-gases in newly manufactured equipment such as domestic refrigerators, freezers and mobile air conditioning in the EU. The use of F-gases will therefore be phased out as these types of systems are replaced by new ones.

However, the use of F-gases in households will increase by 2030 due to the growth of air-to-air and air-to-water heat pumps, *see Climate Status and Outlook 2023*. The industrial gas SF6 is mainly used in the electricity sector and in some high-voltage installations and is approx. 24,000 times more harmful to the climate than CO_2.

F-gases are already regulated and taxed today when the substances are used in the manufacture and maintenance of installations. The rates on F-gases are set per CO_2-eq based on the Global Warming Potential (GWP) of the gases. The tax rates for F-gases are currently balanced according to the current CO_2-eq tax, which in

2023 is DKK 181 per tonne of CO_2-eq. Therefore, there will be no major administrative costs associated with adjusting the current tax.

The EU has revised the current F-gas regulation. This does not affect the assessments for F-gases. The reason for this is that the revised regulation's content has been known for a long time, and therefore, its effect has already been taken into account in the assessments.

With the *Agreement on Green Tax Reform for Industry, etc. from 2022* (S, V, SF, RV and K), which introduces a higher and more uniform CO_2-eq tax, the tax rates for F-gases will no longer be balanced with the CO_2-eq tax for other industries.

The Expert Group's models maintain the symmetry and allow the tax on F-gases to follow the higher and more uniform CO_2-eq tax agreed in the *Agreement on Green Tax Reform for Industry, etc.* including the planned phase-in from 2025-2030.

F-gases are not subject to quotas, which means that emissions will be subject to a tax of DKK 750 per tonne of CO_2-eq. If the tax is raised from the current DKK 181 per tonne of CO_2-eq to DKK 750, it is estimated that this will result in additional revenue after statics effects and behavioural response of approx. DKK 80 m, as well as a CO_2-eq reduction in 2030 of approx. 0.1 m tonnes, *see Table 3.6*.

Table 3.6. Consequences of raising the tax on F-gases from DKK 181 per tonne of CO_2-eq to DKK 750 per tonne of CO_2-eq in 2030

CO_2-eq reductions	**Immediate revenue**	**Revenue after behavioural response**	**Shadow price**
m tonnes	*DKK m*	*DKK m*	*DKK per tonne of CO_2-eq*
0.1	130	80	475

Note: Estimates are subject to uncertainty and are consolidated in connection with legislative proposals. Legislative proposals, including the reduction effect, must be consolidated in relation to inclusion in Climate Status and Outlook.
Source: Own calculations.

The tax payment is incurred in the production of an installation that uses F-gas. Assuming that the tax payment is passed on to the price of the installation in the long term, it is estimated that a tax increase to DKK 750 per tonne of CO_2-eq will mean that the acquisition price for, e.g. large heat pumps, which must have a maximum of coolant per unit corresponding to 5 tonnes of CO_2-eq, will increase by approx. DKK 2,800 per heat pump.

Similarly, the acquisition price of a typical household's air-to-air heat pump is estimated to increase by approx. DKK 480 per heat pump as a result of the tax increase. For an air-water heat pump, the acquisition price will increase by approx. DKK 960 per heat pump. The Danish Energy Agency's technology catalogue estimates the lifespan of individual heating systems for households to be around 15 years. This means that the annual cost for a typical household would be DKK 32 per year for an air-to-air heat pump, while it would be DKK 64 per year for an air-to-water heat pump. The tax payment is incurred when f-gases are used in the manufacture or maintenance of an installation.

An increase in the tax is estimated to have financial consequences for the business sector corresponding to the immediate income effect, which amounts to approx. DKK 130 m annually. The tax is expected to be passed on in higher prices to consumers over time. Today, there are approx. 1,200 companies in the relevant sectors.

Biogas leakage

The Expert Group does not recommend a CO_2-eq tax on emissions from biogas leakage.

Biogas production is associated with methane loss from biogas plants due to leaks etc. With the *Climate Agreement on Green Power and Heat from June 2022* (S, V, SF, RV, Ø, K, DF, LA, Æ and KD), a new regulation has been agreed upon to reduce leakage from biogas production, which, among other things, involves review and control of plants, plant improvements and a point source limit of no more than 1 per cent for upgrading plants. The regulation came into effect from 1 January 2023. It is estimated that the new regulation will reduce CO_2-eq emissions by 0.5 m tonnes of CO_2-eq from 0.8 CO_2-eq to 0.3 m tonnes of CO_2-eq in 2030.

It is currently not considered technically feasible to further reduce methane leakage, as production cannot be hermetically sealed. Therefore, it is very uncertain whether a tax on methane emissions will reduce leakage or increase production costs.

The introduction of a CO_2-eq tax on biogas leakage will also require valid measurements of methane emissions from each individual plant. This is not the case today, where emissions are calculated based on random sampling. If it becomes possible to obtain the necessary data in the future, it may be possible to regulate biogas leakage more effectively in the future.

Landfills

The Expert Group does not recommend a CO_2-eq tax on emissions from landfills, as the administrative and economic consequences of such a tax are not considered to be proportional to the effect on reducing greenhouse gases.

Landfilled waste can produce landfill gas, which contains the greenhouse gases CO_2 and methane. A large part of landfill gas is formed by the biological decomposition of organic material. The amount of methane from the landfill sector has been decreasing since 1997, when a ban on landfilling waste suitable for incineration, including organic waste, came into effect. This means that the methane formation potential of waste going to landfill today is 89 per cent lower than it was in 1990. As historically landfilled waste gasifies, the amount of methane from the landfill sector is decreasing and is estimated to continue to decrease until 2040.

There is currently a tax on landfill of waste amounting to DKK 475 per tonne of waste, which, including operating costs at the specific landfill site, is paid as part of the so-called landfill tariff. Waste that is currently sent to landfill is not considered recyclable or suitable for incineration, which is why landfill is often the only environmentally sound option.

Under the auspices of the political agreement on the *Climate Plan for a green waste sector and circular economy from June 2020* (S, V, RV, SF and LA), it has been agreed that initiatives will be launched that can lead to locally profitable socio-economic reduction measures at landfills and waste treatment plants. This work is still ongoing.

The most commonly used measure to reduce emissions from landfills are biocovers, which are a layer of biogenic material that keeps the landfill gas from being released into the atmosphere. The support scheme for the use of biocovers is still in the establishment and monitoring phase and is expected to be finalised by the end of 2027.

Composting garden and park waste

The Expert Group does not recommend a CO_2-eq tax on emissions from composting of garden and park waste[28], as the effect is assessed to be limited*, and* therefore the administrative and economic consequences of a tax are not proportional to the CO_2-eq effect.

In Denmark, around 1,000,000 tonnes of garden waste are produced annually, with around 75 per cent coming from households, e.g. at recycling stations, and around 25 per cent from businesses.

With the *Climate Plan for a Green Waste Sector and Circular Economy from June 2020 (*S, V, RV, SF and LA*)*, it has been decided to initiate an analysis and then take measures to reduce greenhouse gas emissions from garden waste by at least 20 per cent. Measures can include stricter operating conditions to ensure that anaerobic conditions are not created in the composting process, which gives rise to methane emissions.

A CO_2-eq tax on composting garden park waste could economically encourage more garden waste to be sold for biogasification or conversion to CO_2-eq-reducing composting methods, or to be exported for recycling in neighbouring countries, which, all else being equal, would reduce national greenhouse gas emissions. Recycling garden park waste, including composting, is an important part of recycling nutrients such as phosphorus, nitrogen and potassium back into agricultural soil. Composting garden waste is therefore instrumental in meeting the EU's binding recycling target for household-like waste by 2025, as garden waste has a very high recycling rate. Denmark's actual recycling rate was 46 per cent in 2021 and will increase to 55 per cent by 2025.

Wastewater

A CO_2-eq tax on wastewater emissions is not included in the expert group's models, as it is not considered to have any significant effect in relation to the agreed limit values. In this context, the Expert Group notes that the previously agreed limit values should be introduced.

There are approx. 100 municipally owned wastewater companies in Denmark, with some facilities both transporting and treating wastewater, while a smaller number only transport wastewater. The vast majority of discharges are generated by the biological treatment of wastewater. Nitrous oxide emissions can be reduced by either controlling the treatment processes or covering the treatment plant and capturing the gases.

There is currently a tax on wastewater. The wastewater treatment plant pays a tax on the discharge of domestic and industrial wastewater *after* treatment. It is collected from wastewater treatment plants based on information about residual impurities in the wastewater, including phosphorus and nitrogen discharged, and via sewerage authorities for properties that are not connected to communal sewerage.

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[28] It should be noted that the designation of the fraction "garden and park waste" is referred to as "garden waste" in other contexts.

As part of the *Climate Plan for a Green Waste Sector and Circular Economy (*S, V, RV, SF and LA*)* from 2020, it was agreed to introduce limit values for nitrous oxide emissions from wastewater treatment plants that treat wastewater for minimum 30,000 person equivalents (PE). This means that the limit values cover approx. 65 per cent of the wastewater volume and 75 per cent of the nitrous oxide emissions from the process. The reduction effect of the limit value is expected to be approx. 0.1 m tonnes of CO_2-eq in 2030. This effect is currently not recognised in the Climate Projection. Based on the experience gained, it will be discussed with the parties to the agreement by 2025 at the latest whether the limit should be reduced from 30,000 person equivalents (PE) to a lower level. It is estimated to have a reduction potential of approximately 0.02 m tonnes CO_2-eq. The possibilities of imposing a CO_2-eq tax on wastewater discharges can be revisited at a later date, e.g. by revisiting the effect of the limit values.

Others

The emissions primarily include non-sectoral methane and nitrous oxide emissions from biomass burning, other emissions from, e.g. indirect CO_2-eq emissions from industry, which occur when CO_2 is converted to other greenhouse gases in the atmosphere, fugitive emissions from oil and gas storage facilities, accidental fires of buildings and vessels, etc.

These emissions are generally limited, and regulation will not be able to be administered due to a lack of options for control and identification, which is why the Expert Group has chosen not to regulate them in its models.

Advantages and Disadvantages of Tax on End Consumption

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4. Advantages and Disadvantages of Tax on End Consumption

The additional terms of reference state that the Expert Group must, as part of its final report, *"analyse the pros and cons of imposing a CO_2-eq tax on end consumption".* This section presents the Expert Group's analysis of the pros and cons of such a tax, exemplified by a tax on the end consumption of climate-impacting foods.

A tax on end consumption will only to a limited extent contribute to meeting the national 70 per cent target linked to emissions from domestic production. As a result, a tax on end consumption will only allow for a very limited reduction of a tax at the production stage. In addition, a tax on end consumption is a more imprecise taxation of the actual climate impact than a tax at the production stage.

Based on the analyses below, a climate tax on end consumption is not included in the models presented by the Expert Group in *Chapter 2*.

Characteristics of a consumption tax

A climate tax on the end consumption of climate-impacting food products should ideally be proportional to the total amount of CO_2-eq estimated to have been emitted in connection with the production and transport of the individual taxed product. However, as further explained in the sub-section on administrative issues below, it will be necessary to operate with the same tax rate for all products of a given category, such as beef, based on an estimate of the average climate impact of the product group. This means that individual farmers cannot reduce the tax burden on their products by choosing a more climate-friendly production method. Unlike a production tax on emissions from individual farms, a consumption tax will therefore not incentivise individual farmers to adopt more climate-friendly technologies. This is a significant disadvantage of a climate tax on end consumption.

In return, a climate tax on end consumption will be imposed at the same rate on imported and domestically produced goods of a given type. This prevents the tax from weakening the country's international competitiveness.

On the other hand, a climate tax in the production stage is only imposed on domestic primary food producers and will, thus, all other things being equal, reduce domestic competitiveness. Danish-produced food products will, therefore, to some extent be replaced by imported food products in domestic end consumption, whereby part of the reduction in domestic greenhouse gas emissions may be offset by increased emissions abroad. A production tax can therefore lead to some leakage of greenhouse gas emissions abroad. However, it is important to note that the total emissions abroad are affected by the country-specific targets for greenhouse gas reductions.

The Danish Climate Act states that Danish climate initiatives *"must lead to real, domestic reductions, but we must also ensure that Danish initiatives do not simply move all greenhouse gas emissions outside Denmark's borders".* The Expert Group's terms of reference also state that its recommendations must consider the risk of greenhouse gas leakage.

Against this background, it is discussed below how to counteract greenhouse gas leakage and what role a consumption tax can play in this regard. Next, the appropriateness of a consumption tax is discussed in light of the Danish national climate targets and international commitments.

Mitigation of greenhouse gas leakage – Fundamental considerations

The theoretical research literature agrees that a country can most purposefully counteract greenhouse gas leakage by combining a climate tax in the production stage with an import tax on CO_2-eq-intensive goods and a tax exemption for emissions from production to export, *see e.g. Hoel (1996)*.[29] This ignores the practical challenges of implementing such a system, which are discussed below. In addition, the system may violate WTO rules on international trade cooperation as well as EU law.

However, research literature has also pointed out that it is possible to counteract greenhouse gas leakage and reduce the country's global climate footprint by combining a climate tax at the production stage with a climate tax at the consumption stage and a production subsidy for domestic producers, *see e.g. Böhringer et al. (2017) and Kruse-Andersen and Sørensen (2022)*.[30] The consumption tax must then be imposed on all imported and domestically produced goods at a rate that reflects the estimated CO_2-eq content of the goods, and the production subsidy to the individual domestic producer must be proportional to the company's production multiplied by an estimated average CO_2-eq intensity of production in the industry to which the company belongs. As the individual company typically has little influence on the average CO_2-eq intensity of the industry, the climate tax at the production stage will encourage companies to reduce their emissions, while the production subsidy neutralises the negative impact of the tax on the competitiveness of the typical company in the industry.

Thus, if a production subsidy is introduced, the tax at the consumption stage is not necessary to protect domestic competitiveness. The consumption tax, on the other hand, aims to lower the country's global climate footprint by curbing the consumption of climate-impacting goods. The motivation for such a combined tax and subsidy model is thus that the domestic country not only has an objective to avoid carbon leakage from domestic production, but has a broader objective to

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[29] See M. Hoel (1996). Should a carbon tax be differentiated across sectors? Journal of Public Economics 59, pp. 17-32.

[30] See C. Böhringer, E.J. Balisreri, T.F. Rutherford (2017). Robust policies to mitigate carbon leakage. Journal of Public Economics 149, pp. 35-46, and P.K. Kruse-Andersen and P.B. Sørensen (2022). Optimal energy taxes and subsidies under a cost-effective unilateral climate policy: Addressing carbon leakage. Energy Economics 109, May 2022, 105928.

lower the overall global climate footprint from domestic production *and* consumption activities.

In a Danish context, the difficulty with the described tax and subsidy model is that the aforementioned production subsidy to domestic producers may be in conflict with EU law. In addition, there can be serious practical difficulties in delineating the different sectors (or forms of operation in agriculture) when calculating the average CO_2-eq intensity of the sector (operating branch) and when assigning the individual business (agricultural business) to the relevant sector (operating branch).

If, for these reasons, a production subsidy is abandoned, you are left with the domestic tax at the production stage, which can lead to carbon leakage, and the consumption tax. To reduce the leakage effect, the tax can be lowered at the production stage. This will increase emissions from domestic production, and since the carbon leakage rate will normally be less than 100 per cent, *see Beck et al. (2023)*[31], global emissions will also increase, albeit to a lesser extent. If you want to avoid this increase in the global climate footprint, you can choose to raise the consumption tax to curb the consumption of imported as well as domestically produced climate-impacting goods. A (partial) restructuring from taxation at the production stage to taxation at the consumption stage can thus in principle reduce the loss of domestic competitiveness and the resulting greenhouse gas leakage without increasing the country's global climate footprint.

Tax at the consumption stage versus tax at the production stage – The importance of climate policy objectives

A climate tax at the consumption stage can theoretically be an appropriate instrument if there is a political objective to reduce Denmark's global climate footprint.

However, international climate cooperation is based on the territorial principle, where each country commits to reducing its own emissions. For example, the Danish Climate Act stipulates that emissions from Danish territory (calculated according to UN guidelines) must be reduced by 70 per cent in 2030 compared to emissions in 1990. In relation to the EU, Denmark is also committed to reducing the accumulated territorial emissions from the Effort Sharing Regulation sector and the LULUCF sector by a certain amount by 2030, which represents Denmark's contribution to the fulfilment of the Paris Agreement through EU cooperation.

These national and international climate policy objectives reflect the fundamental principle of European and global climate cooperation that each country is responsible for the emissions from its territory, which primarily stem from the production activities that take place in the country, including the production of domestic transport services by households for their own consumption. The rationale behind the territorial principle is that it is easier for nation states to measure and regulate territorial emissions than to calculate and control the country's global climate footprint, as the climate footprint of imported goods depends on the production methods and climate regulation of production in the country from which the import originates.

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[31] See U.R. Beck, P.K. Kruse-Andersen, L.B. Stewart (2023). Carbon leakage in a small open economy: The importance of international climate policies. Energy Economics 117, 2023, 106447.

When the political objective is to regulate greenhouse gas emissions from the domestic territory, the most targeted approach is to impose a climate tax on emissions from domestic production. Admittedly, a tax on the end consumption will also lower domestic emissions to the extent that a lower domestic production of these goods offsets the resulting decrease in the consumption of climate-impacting goods. However, since the consumption tax does not include emissions from the part of domestic production that is exported, achieving a given target for reducing domestic emissions through a consumption tax rather than a tax in the production stage would require a significantly higher tax and thus entail a much higher socio-economic cost.

Food consumption and greenhouse gas emissions – a numerical explanation

Table 4.1 provides an overview of the expected food consumption of Danish households in 2030 and the resulting CO_2-eq emissions in Denmark and abroad. The estimate is associated with considerable uncertainty.

Table 4.1. Danish households' food consumption in 2030 (DKK bn) and the resulting CO_2-eq emissions (m tonnes)

Households' food consumption delivered from	Danish products			Imported products	
	Value of consumption, DKK bn	Emissions in Denmark, CO_2-eq	Emissions abroad, CO_2-eq	Value of consumption, DKK bn.	Emissions abroad, CO_2-eq
Agriculture and horticulture	2.4	0.3	0.04	3.3	0.6
Cattle slaughterhouses	0.9	0.3	0.02	1.7	0.2
Pig slaughterhouses	6.1	0.4	0.1	3.6	0.3
Poultry slaughterhouses	1.2	0.04	0.03	1.4	0.1
Dairies	8.2	1.2	0.2	3.1	0.3
Fishing industry	0.5	0.01	0.02	0.9	0.04
Bakeries and bread factories	6.9	0.2	0.2	3.5	0.2
Other food industry	7.9	0.3	0.3	17.2	1.0
Other industries (wholesale and retail trade, etc.)	59.2	0.3	0.4	2.7	0.2
Total	**93.2**	**3.1**	**1.2**	**38.3**	**3.1**

Note: Food consumption is calculated in 2023 producer prices. All figures are rounded.
Source: Own calculations and the Danish Energy Agency.

The figures in the first column of the table show how much of food consumption is made up of domestic deliveries from primary agriculture, slaughterhouses, dairies, bread factories and other food industries, etc. The penultimate figure in the first column shows that a very large part of the value of Danish-produced food products is made up of the value added created in the Danish wholesale and retail trade in food.

The Danish production of and trade in food products results in greenhouse gas emissions from Danish territory. These emissions are listed in the second column of *Table 4.1*. Danish food production and trade also require the import of several inputs for agriculture, slaughterhouses, dairies, etc., and the foreign production and transport of these inputs give rise to emissions abroad, which are shown in the third column of the table.

In addition, Denmark imports processed food from foreign farms, slaughterhouses, dairies, etc. The value of these imports and the foreign emissions from the production of these imports are shown in the fifth and sixth columns of *Table 4.1*.

The emissions derived from Danish households' consumption of plant-based foods primarily appear in the top row of the table (Agriculture and horticulture), where total emissions in Denmark and abroad amount to just over 0.9 m tonnes of CO_2-eq. In comparison, the figures in *Table 4.1* imply that the total emissions from Danish and foreign cattle slaughterhouses, pig slaughterhouses and dairies resulting from Danish food consumption amount to 3 m tonnes of CO_2-eq. The bottom row of the table shows that Danish food consumption results in global emissions totalling 7.4 m tonnes of CO_2-eq, of which emissions from the food industries in the top eight rows of the table amount to 6.5 m tonnes of CO_2-eq.

Consumption tax versus a climate tax in the production stage

The following presents model calculations of the effects of a consumption tax on climate-impacting foods and a tax on greenhouse gas emissions from domestic agricultural production. Furthermore, the effects of a combination of the two types of tax are examined.

As shown in *Table 4.1*, food deliveries from cattle and pig slaughterhouses and dairies are the main contributors to climate impact. Against this background – and because a system of differentiated climate taxes on all food consumption would involve very large administrative challenges – it is assumed that it is possible in relation to EU law to limit the consumption tax system to three separate unit taxes on the estimated CO_2-eq emissions derived from Danish households' consumption of beef, pork and dairy products. It is also assumed that all types of e.g. beef are taxed at the same rate.

In the calculations below, the tax rate on beef, for example, is determined on the basis of the CO_2-eq emissions in Denmark and abroad that beef from Danish cattle slaughterhouses to Danish households is estimated to cause in 2030. Thus, it is calculated how many tonnes of CO_2-eq per DKK of consumption value (in 2023 prices) are emitted from the production of the agricultural raw materials and all other inputs that Danish cattle slaughterhouses buy from Danish and foreign suppliers of inputs to the cattle slaughterhouses. Similarly, an average total CO_2-eq emission in Denmark and abroad has been calculated per krone of consumption of pork and dairy products delivered from Danish pig slaughterhouses and dairies.

To avoid the tax being perceived as discriminatory, and thus incompatible with EU law and the WTO, it is assumed that Danish and imported food products of a given category are subject to the same consumption tax rate. Thus, for tax purposes, it is assumed that the CO_2-eq intensity of Danish and imported foods of a given type is the same.

The consumption tax rate is assumed to be DKK 750 per tonne of estimated CO_2-eq content in the given food category. The tax is generally levied at the retail level.

The production tax rate is also assumed to be DKK 750 per tonne of CO_2-eq emitted from each farm and is assumed to be collected from each farmer.[32]

Table 4.2 shows the emissions covered by the two types of tax in the calculations, compared to the total emissions from the production and consumption of food. It is assumed that the tax base does not include the emissions from wholesale and retail trade in food.

The central difference between the two tax types is that the consumption tax, unlike the production tax, does not affect the emissions from the production of Danish food for export, but that the consumption tax, unlike the production tax, includes the estimated emissions abroad from the production of imported finished food and from the production of imported inputs in Danish food production (where the emission coefficients in foreign and Danish production are assumed to be the same as mentioned).[33]

Table 4.2 shows that the base for the consumption tax is significantly narrower than the base for the production tax. This primarily reflects the fact that Denmark's food exports are larger than its food imports, so including exports rather than imports in the tax base provides a broader tax base. Even if all emissions from total Danish food consumption (excluding emissions from wholesale and retail trade) were included in the tax base, according to the figures in *Table 4.2*, the tax base would only amount to 6.5 m tonnes of CO_2-eq, whereas the base for the production tax is 8.1 m tonnes of CO_2-eq, even if emissions from carbon-rich agricultural land are not included.

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[32] The production tax is assumed to consist of a combination of a fertiliser tax and a set of taxes on the different categories of livestock corresponding to the tax base in *Chapter 2* of the report. Emissions from carbon-rich agricultural land are thus not included in the basis for the production tax. In the production levy system, to ensure comparability with the consumption levy, there is no requirement for the use of the instruments tent covering and nitrification inhibitors, but the high levy rate makes it favourable for farmers to use feed additives, which is taken into account in the model calculation.

[33] The assumed emission coefficients in foreign production in *Table 4.2* thus deviate from the foreign emission coefficients in *Table 4.1*, where an international input-output table is used to estimate the actual foreign emissions per unit produced.

Table 4.2. Emissions subject to taxes

m tonnes of CO_2-eq	Emissions	Emissions subject to consumption tax	Emissions subject production tax
Danish production for food consumption of Danish households	3.1	1.9	2.1
Danish production for export	7.3	0	6.0
Imported Inputs for Danish food production	1.2	0.4	0
Import of finished food products	3.1	0.9	0
Total	**14.7**	**3.2**	**8.1**

Note: Emissions from domestic production are based on industry-specific emissions from GreenREFORM. Emissions from domestic production for domestic consumption and export exclude emissions from carbon-rich agricultural land. Emissions include emissions from agriculture and other industries that contribute to the value of food consumption. All figures are rounded.
Source: Own calculations and the Danish Energy Agency.

Table 4.3 summarises the modelled effects of the two alternative tax systems. In addition, the effects of a combined tax system are shown, where both a consumption tax of DKK 750 per tonne of CO_2-eq and a production tax of DKK 700 per tonne of CO_2-eq are introduced. Such a system achieves approx. the same reduction in domestic emissions as a production tax of DKK 750 per tonne of CO_2-eq alone. The production tax in this example only includes fertiliser, liming and livestock, and therefore does not include other measures included in *Chapter 2*, including emissions from carbon-rich agricultural land. For this reason, the results, including climate impact and shadow price, cannot be directly compared with model 1 in *Section 2.3*.

The premise for such a combined tax system in the third column of the table is that there is a political objective that agriculture should contribute a certain reduction of domestic emissions. It should be noted that in the combined tax system, there is a double taxation of the CO_2-eq content in the part of the domestic agricultural production that goes to domestic consumption, as this part of the production is subject to both the production tax of DKK 700 per tonne of CO_2-eq and the consumption tax of DKK 750 per tonne of CO_2-eq. It is noted that an alternative combined tax system, where a consumption tax is levied on imported goods as a counterpart to a production tax on domestically produced goods, is considered very difficult to reconcile with EU law.

In the modelling calculations in *Table 4.3*, the calculation of the effects on foreign emissions takes into account the derived effects on the foreign economy when Denmark's exports and imports of food products change. This takes into account the fact that an increase in foreign agricultural production in order to increase exports to Denmark will require a transfer of labour, capital, energy and other inputs from other parts of the foreign economy to foreign agriculture. This transfer of resources will, all else being equal, reduce emissions from other parts of the foreign economy, thereby limiting the overall carbon leakage effect of a production tax on Danish agriculture.

The table shows that the production tax alone reduces emissions in Denmark by approx. 2.8 m tonnes of CO_2-eq, but increases emissions abroad by just over 0.7 m tonnes of CO_2-eq in the lower estimate for carbon leakage, *see Appendix 7.8*, whereby global emissions are only reduced by just over 2.1 m tonnes of CO_2-eq. This means that a reduction of domestic emissions by 1 tonne increases emissions abroad by approx. 0.25 tonnes, corresponding to a carbon leakage rate of approx. 25 per cent from the production tax alone, given the assumptions about climate policy abroad that are used as a basis for the lower estimate in the carbon leakage calculations, *see Appendix 7.8*. The effect of the consumption tax on foreign emissions is slightly negative, but close to zero. The consumption tax does slightly curb the import of climate-impacting food products, but since the tax revenue is assumed to be returned to consumers, the tax primarily leads to a change in the composition of private consumption, whereby the lower import of meat and dairy products is offset by increased imports of other consumer goods whose production gives rise to emissions abroad.

Table 4.3. Effects of climate taxes on consumption and production

	Consumption tax	Production tax	Combination
Tax (consumption/production), DKK per tonne of CO_2-eq	750	750	750/700[1)]
CO_2-eq reduction (m tonnes)			
Denmark	0.2	2.8	2.8
Abroad	~0	-0.7	-0.6
Globally	0.2	2.1	2.2
Change in production (per cent)			
Crops	0.2	-7.9	-7.5
Cattle	-1.9	-20.2	-20.9
Pigs	-0.6	-17.7	-17.0
Price change (per cent)			
Consumer price index for food products	1.2	0.3	1.4
Consumer price index for food products (excluding drinks)	1.6	0.4	2.0
Decline in land values (excl./incl. afforestation subsidies)	0.6 / -11.1	16.8 / 8.8	16.4 / 8.3

Shadow prices, excluding side effects (DKK per tonne of CO_2-eq)			
Shadow price on domestic reductions	3,250	450	650
Shadow price on global reductions	3,250	600	800

Note: The consumption tax is levied on the consumption of beef, pork and dairy products. The production tax does not include emissions from carbon-rich agricultural land. All figures are rounded.
1) The consumption tax is DKK 750 per tonne of CO_2-eq, while the production tax is DKK 700 per tonne of CO_2-eq
Source: Own calculations

According to the third column in *Table 4.3*, the introduction of a consumption tax of DKK 750 per tonne of CO_2-eq on beef, pork and dairy products would allow for a reduction in the production tax from DKK 750 to DKK 700 per tonne of CO_2-eq if the same reduction in domestic emissions from Danish agriculture is to be maintained. This means that an increase in the consumption tax rate of DKK 1 will only enable a reduction in the production tax rate of just under DKK 0.7, and that a consumption tax must be 15 times as high as a production tax to ensure the same domestic CO_2-eq reduction.

This partly reflects the fact that the consumption tax base is significantly narrower than the production tax base. If one simplistically assumes that the effect of a tax charged at a given rate is proportional to the tax base, the figures in *Tables 4.2* and *4.3* imply that a consumption tax would have to be almost 6 times as high as a production tax to ensure the same domestic CO_2-eq reduction if the tax base for the two tax types had the same size.[34]

This result shows that a tax at the production stage is a much more effective instrument to reduce domestic emissions than a consumption tax. This is due to several factors. Firstly, the consumption of the particularly climate-impacting foods is relatively insensitive to price increases, even when taking into account the possibility of substitution towards less climate-impacting plant-based foods, *see Box 4.1*. The production tax, on the other hand, hits exports, which are far more price elastic than domestic food consumption due to international competition in the export market. Therefore, the production tax has a significantly higher impact on domestic agricultural production.

Secondly, the production tax is directly targeted at lowering domestic emissions, whereas the consumption tax does not include emissions from domestic production for export, but works in part by lowering food imports and thus emissions abroad.

Thirdly, a large part of the effect of a consumption tax on food consumption can also be achieved through a production tax, as approximately half of the cost increase due to a production tax will be passed onto consumer food prices, according to the modelling calculations.

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[34] According to *Table 4.2*, the production tax base is 8.1/3.2 = 2.53 times larger than the consumption tax base. If the basis for the two types of tax were the same, the effects of the consumption tax would therefore be approx. 2.53 times greater than the effects shown in *Table 4.3*. In this case, the consumption tax rate would only need to be 15/2.53 = 5.93 times higher than the production tax rate to ensure the same CO_2-eq reduction.

Fourthly, unlike the consumption tax, the production tax gives the individual domestic agricultural company a direct incentive to reduce emissions through technical measures such as feed additives, which in the model calculations contribute CO_2-eq reductions of almost 0.5 m tonnes.

The figure of production change in *Table 4.3* further help to explain the difference in the impact of the two types of taxes on domestic emissions. It can be seen that the production tax leads to a decrease in domestic animal agricultural production in the order of approx. 20 per cent, whereas the consumption tax only reduces domestic animal production by 1-3 per cent. The structural effect of a consumption tax is thus much smaller, which can be seen as an advantage, but the counterpart to this is that the consumption tax only contributes very little to fulfil Denmark's obligations to reduce territorial emissions.

As the consumption tax is an ineffective tool for reducing domestic emissions, the socio-economic shadow price of domestic CO_2-eq reductions using this instrument is almost five times as high as that of domestic CO_2-eq reductions using a production tax, *see the penultimate row in Table 4.3*. The consumption tax is a slightly more effective instrument for reducing emissions abroad, as it does not result in carbon leakage, unlike the production tax, but nevertheless, the bottom row in *Table 4.3* shows that the shadow price of reducing *global* emissions (the sum of domestic and foreign emissions) is more than three times higher with a consumption tax than with a production tax. This is because the production tax is a much more effective instrument for lowering domestic emissions.

Box 4.1

How does food consumption react to a climate tax in the consumption stage?

If a consumption tax is introduced on particularly climate-impacting foods, it has three immediate consequences for households: 1) The tax erodes real disposable income, so households will have to reduce their overall consumption over time. 2) Food becomes more expensive compared to other goods. 3) The particularly climate-impacting foods become more expensive compared to other foods. The first effect can be largely eliminated if the tax revenue is channelled back to households, which is assumed in the following.

The second effect 2) encourages consumers to lower the consumption of food in relation to the consumption of other goods. The size of this substitution effect depends on the so-called elasticity of substitution between food and other goods, denoted by s_F in equation (1) below. This elasticity of substitution indicates the percentage decrease in the ratio between food consumption and other consumption when the relative price of food increases by 1 per cent.

The third effect 3) encourages consumers to reduce their consumption of particularly climate-impacting foods relative to the consumption of other foods. The strength of this substitution effect depends on the elasticity of substitution s_K between the particularly climate-impacting and the less climate-impacting foods, which indicates the percentage decrease in the ratio between the consumption of these two food groups when the relative price of the climate-impacting foods increases by 1 per cent.

The size of the total effect of the consumption tax is measured by the price elasticity of demand for climate-impacting food products, which indicates the percentage decrease in the consumption of these products when their relative price increases by 1 per cent. The price elasticity depends on the above-mentioned elasticities of substitution and on the weight with which the taxed and non-taxed food are included in the household budget. If one assumes that consumers seek to maximise the satisfaction of needs they can achieve with a given total consumption budget, it can be shown that the price elasticity of demand for climate-damaging foods (denoted e_K) is given by the formula

$$e_K = (a_K - a)\, s_F + (1 - a_K)\, s_K \qquad (1)$$

where a is the share of the household's *total* consumption budget that goes towards the purchase of climate-impacting food products, and a_K is the share of the household's total *food* budget that goes towards the purchase of these products. Since only a portion of the total household budget is spent on food purchases, a_K is greater than a. Thus, the expression $(a_K – a)\ s_F$ on the right-hand side of (1) is positive and captures the effect of an increase in the price of climate-impacting foods, encouraging a decrease in total food consumption. In contrast, the expression $(1\text{-}a_K)\ s_K$ reflects the effect of encouraging consumers to shift food consumption towards less climate-impacting foods.

Several empirical studies indicate that substitution between household consumption of food and non-food goods is limited, which is intuitive as food fulfils basic needs. An empirically plausible value for the elasticity of substitution between food and non-food products is $s_F = 0.3$. The possibility of substitution between particularly climate-impacting foods (e.g. meat and dairy products) and less climate-impacting foods is greater, and an empirically plausible size of the elasticity of substitution is estimated to be in the order of $sK = 1.2$. In Denmark, food consumption accounts for approx. 10 per cent of total private household consumption. For example, if the consumption of particularly climate-impacting foods accounts for half of total food consumption, i.e. $a_K = 0.5$, this means that the share of these products in the total household consumption budget is $a = 0.1×0.5 = 0.05$. With all these parameter values, it follows from equation (1) that the price elasticity of demand for climate-impacting food is

$$e_K = (0{,}5 – 0{,}05)×0{,}3 + (1\text{-}\ 0{,}5)×1{,}2 = 0{,}735 \qquad (2)$$

This result means that the consumption of particularly climate-impacting foods will fall by just over 0.7 per cent when their relative price increases by 1 per cent. According to *Table 2* above, a consumption tax of, for example, DKK 750 per tonne on particularly climate-impacting foods would increase the average price of all foods (excluding beverages) by almost 1.5 per cent. If it is roughly assumed that the price of particularly climate-impacting products increases by double, as only these products are affected by the tax, it follows from the estimate of the price elasticity in equation (2) that the consumption of climate-impacting foods will fall by 3 × 0.735 = 2.2 per cent.

Greenhouse gas emissions from the production and transport of food are assumed to decrease roughly proportionally with consumption. For example, if you want to reduce emissions caused by the consumption of particularly climate-impacting foods by 10 per cent, it follows from the price elasticity in (2) that the price of these products must increase by 10/0.735 = 13.6 per cent, which would require a consumption tax that is many times higher than the DKK 750 per tonne mentioned above.

The analysis above is stylised and is only intended to illustrate some basic relationships.

The main conclusion from the modelling calculations above is that the introduction of a consumption tax in combination with a production tax and as a partial substitute for a production tax only to a very limited extent can reduce the adjustment burden of agriculture when there is a target to reduce emissions from domestic agriculture by a certain amount. Such a combined tax system also implies a higher shadow price on domestic CO_2-eq reductions than the pure production tax, as food consumers will bear a higher burden. The shadow price of global CO_2-eq reductions from a production tax is subject to considerable uncertainty due to uncertainty about the size of the leakage effect. If the leakage effect is larger than the one used in the modelling above, the difference between the shadow prices of global CO_2-eq reductions under the two tax forms narrows, but in any case, the Expert Group's analysis indicates that the shadow price is significantly higher under a consumption tax than under a production tax.

Administrative issues

A climate tax at the consumption stage would need to be designed to reflect how much greenhouse gas is emitted globally in the production and transport of the product being consumed. In practice, this is very uncertain and administratively difficult. This is particularly due to the fact that the domestic authorities only have limited information about how production and transport abroad has taken place, *see*

Box 4.2.

Box 4.2

Administrative aspects of a CO_2-eq tax at the point of consumption – an example with beef

A CO_2-eq tax on beef would ideally be designed to reflect how much greenhouse gas is emitted during the production and transport of each type of beef.

Cattle become beef at a slaughterhouse when they are slaughtered. If the emissions associated with beef production are to be reflected 1:1 in the tax, it would require the authorities to have detailed knowledge of the production method and transport of the product, e.g. under what conditions the cattle have lived, what feed they have consumed, breed, weight, etc. All of these factors must then be converted into greenhouse gas emissions. These conditions will vary depending on where the cattle are raised and where they are taken after slaughter. In addition, there will be a lot of variation across different types of beef and products where beef is a proportion of the product. Furthermore, beef that is not sold as a product in itself but is included in other products, such as pizza, cold meats, etc., will have to be taxed.

Such detailed information is very difficult for the taxpayer to provide and for the authorities to verify for a tax base. This applies in particular to detailed information from exporters of beef from remote countries to Denmark, where an effective control by the Danish tax authorities is unlikely to be possible, as the Danish authorities do not have detailed information on how production and transport abroad has taken place. In addition, foreign-produced beef is, all other things being equal, expected to have longer transport distances and thus emit more greenhouse gases, which means that a higher tax must be paid on foreign meat. This may raise obstacles under EU law due to the prohibitions on discrimination against foreign products and quasi-customs charges.

For these reasons, it is deemed necessary to base a beef tax on an estimate of the average CO_2-eq emissions per kilo of meat consumed. It may be possible to try to differentiate the tax across the main categories of beef, but this would raise difficult administrative demarcation issues. In any case, using an estimated average emission for a given category of meat would mean that individual producers would not be incentivised to switch to more climate-friendly production methods, as this would not trigger a lower tax on their product. Furthermore, for practical and EU law reasons, a standard rate of tax could hardly be higher for imported goods than on similar domestically produced goods, even if the imported goods have undergone a longer transport.

If the tax is calculated and imposed late in the retail chain, e.g. just before the sale to the consumer (to include all transport to the supermarket in the tax base), the supermarket will be the one to calculate and declare the tax. This will result in an administrative burden for supermarkets, which, like the tax, is expected to be passed on in consumer prices. In addition, a tax imposed late in the chain will mean a large number of taxable businesses with a significant need for control.

A state-controlled climate label on all food products (both imported and domestically produced) could possibly solve the administrative challenges and form the basis for a tax late in the chain, but would still present control challenges in relation to foreign food products.

A tax at the production stage, on the other hand, does not require knowledge of the form of production and transport abroad.

The Expert Group notes that a Danish task group has been set up, which in its report recommends that a state-controlled climate label be established, where all foods are ranked according to their climate footprint.[35]

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[35] See, for example, the Danish Veterinary and Food Administration: "I Udvikling af et klimamærke til fødevarer - anbefalinger fra Arbejdsgruppen" (Developing a climate label for food products - recommendations from the Sub-Commission). April 2023 (https://foedevarestyrelsen.dk/Media/638207095580381128/Klimam%C3%A6rke_anbefalinger%20fra%20arbejdsgruppen_27.%20april%202023.pdf)

Administrative issues in relation to EU law

It is considered possible within EU law to introduce a combination of a production and consumption tax in the case analysed above, where the consumption tax covers both domestically and foreign-produced goods for domestic consumption.

A combination of production and consumption tax, on the other hand, is considered very difficult to implement in accordance with EU law if you alternatively want to impose a consumption tax on imported goods as a counterpart to a production tax on domestically produced goods.

The starting point in EU law is that no tariff-like measures may be established within the EU customs union.

It is not considered possible to impose a consumption tax on imported goods from e.g. cattle and pigs (meat and dairy products) at the same time as the tax at the production stage, as this inherently takes place outside Denmark. Instead, a consumption tax on imported goods would have to be tied to other conditions, e.g. after slaughter when the meat is sold for retail consumption or for further processing. As the national CO_2-eq tax and the consumption tax on imported goods cannot be imposed at the same time or in the same stage, such a combination of production and consumption tax would probably constitute a quasi-customs tax that is not compatible with EU law.

Even if it were possible within the framework of EU law, it would still be virtually impossible in practice to align the rate of excise duty on all different agricultural products (e.g. meat and dairy) with the rate of production tax, as the domestic authorities, as mentioned, have limited information on how production and transport abroad has taken place, *see Box 4.2*.

Conclusions and recommendations regarding a climate tax on end consumption

The Expert Group's analysis of the advantages and disadvantages of a CO_2-eq tax on end consumption can be summarised as follows:

The advantages of a climate tax on end consumption are that it does not weaken domestic competitiveness and thus does not create greenhouse gas leakage. Also, by lowering consumption and imports of climate-impacting goods, it reduces emissions abroad that are derived from domestic consumption. A consumption tax can therefore be a relevant instrument if there is a political objective to reduce Denmark's global climate footprint. However, if the revenue from a consumption tax on particularly climate-impacting foods is returned to consumers, the lower imports of these goods will be offset by increased imports of other consumer goods that also give rise to CO_2-eq emissions abroad, so the overall effect on foreign emissions will be very limited.

The disadvantages of a climate tax on end consumption are that in order to determine the appropriate size of a consumption tax, it will be necessary to quantify how much of a reduction in climate footprint is desired over a given time horizon, and there will be a need to clarify how the climate footprint is to be calculated. However, calculations of a country's global carbon footprint are subject to great uncertainty, partly because the carbon footprint depends on production methods and climate policies abroad, which are constantly changing. Furthermore, there is currently no quantified target for lowering Denmark's global climate footprint. International climate cooperation, on the other hand, is based on a territorial principle, according to which each country is responsible for the emissions from its territory. The 70 per cent target in the Danish Climate Act and Denmark's climate policy commitments to the EU are in line with this principle.

The Expert Group's analyses show that a CO_2-eq tax at the production stage on emissions from individual farms is a far more targeted and cost-effective means of meeting Denmark's national climate targets and international climate commitments than a climate tax on the end consumption of food. This is because a consumption tax will exempt emissions from the extensive Danish food exports and the associated domestic deliveries of agricultural raw materials, and it will not incentivise individual farmers to develop and use more climate-friendly production methods. For these reasons, the introduction of a tax on end consumption will only allow for a very limited reduction of the tax in the production stage if Denmark's territorial climate targets, including the 70 per cent target, are to be met, and the additional socio-economic cost of a consumption tax will be high. In addition, an administrable climate tax on end consumption is considered to involve more imprecise taxation of the actual climate impact than a tax at the production stage.

For this reason, a climate tax on end consumption is not included in the models presented in *Chapter 2*.

Implementation

5

5. Implementation

The Expert Group's terms of reference state that its recommendations must be implementable and take into account legislative, EU law, systemic and administrative consequences. In addition, the Expert Group's terms of reference state that the Expert Group's recommendations must take into account that the development and implementation time for initiatives in the tax area, including new tax structures, is considerable.

The Expert Group has emphasised that the models can be implemented both administratively and legally in time to meet the reduction targets in 2030, and that the implementation is closely linked to the national emissions inventory. The regulatory basis for agriculture's non-energy-related CO_2-eq emissions in the Expert Group's models is based on data that is already being reported today. This means that there is only a limited need for increased reporting from farmers.

On this basis, the assessment is that the models fulfil this requirement, and it is expected that the models for the overall tax and subsidy system, including compensatory measures, can be approved under EU state aid rules.

The regulatory basis is based on the same method used for the national emission inventory of emissions from Agriculture and LULUCF.

CO_2-eq emissions from agriculture and forestry from e.g. livestock, carbon-rich agricultural land, fertilisers and liming are calculated in the emissions inventory as the sum of emissions from agriculture's N various activities, *see Appendix 7.3*. The overall method for calculating the emissions is for each activity denoted by i, to determine an *emissions factor* and *quantity* from which the individual activity's emissions can be determined. Thus, agriculture's CO_2-eq emissions can be summarised as follows:

$$\text{CO}_2\text{-eq emissions} = \sum_{i=1}^{N} \text{quantity}_i \cdot \text{emissions factor}_i$$

The total emissions are calculated based on farm-related activities and standardised emissions factors linked to each activity, as well as, in certain areas, emissions factors for used greenhouse gas-reducing technology. It is thus assumed that emissions from livestock (digestion and fertiliser management) and fertiliser applied to fields can be regulated based on the farm-specific information and activity data used in the national emissions inventory. Similarly, it is assumed that emissions from carbon-rich agricultural land can be regulated based on farm-specific information from the map basis and activity data used in the national emissions inventory.

The farm-specific information and activity data are already registered today via self-reporting from the individual farms as part of the existing environmental and food regulation. However, stable and storage technologies are not self-reported today, neither in the fertiliser accounts nor in other registers in the environmental area. It is assumed that these will be included in the regulatory basis when the necessary registration is provided.

The recommended models involve the implementation of four new taxes (alternatively three new taxes and the restructuring of direct agricultural subsidies to subsidies for reduced fertiliser usage):

1. Tax on livestock. The tax is assumed to be based on the amount of emissions in tonnes of CO_2-eq calculated at the farm level based on reported activity data and the associated emissions factor, *see Appendix 7.6 and sections below*. The calculation of the tax can thereby take into account different activities in line with variations from the emission inventory, where there is variation based on, e.g. breed, weight, types of housing, etc., as well as possibly adoption of technology such as feed additives.

2. Tax on fertiliser on fields or subsidies for reduced fertiliser usage. The tax is assumed to be imposed per kg of nitrogen applied to the field based on the calculation from the emissions inventory, while the subsidy is allocated per reduced kg of nitrogen in relation to the fertiliser standard of the individual field.

3. Tax on agricultural lime on fields. The tax is assumed to be imposed per kg of agricultural lime sold by producers and importers of agricultural lime.

4. Tax on CO_2-eq emitted from carbon-rich agricultural land used as agricultural land. The tax is assumed to be levied per hectare based on existing maps of carbon content in agricultural land at farm level.

As stated in *Section 6.3,* in Q1 2024, the European Commission is expected to present an announcement on a new EU climate target for 2040 and a new climate architecture in the EU after 2030, including an ETS in agriculture at EU level. If an ETS in agriculture at the EU level is adopted, the Expert Group, therefore, recommends that the regulatory basis for national taxes and subsidies supports the work of the European Commission on a regulatory basis for an ETS in agriculture at the EU level.

Tax on livestock, fertiliser application and carbon-rich agricultural land: Farm-related activities and emissions factors

A farm-related inventory of emissions from livestock can be made by multiplying activity data (AD) by an emissions factor (EF) that varies across activities, in:

$$\text{Farm-related inventory of emissions from livestock} = \sum AD_i * EF_i$$

On this basis, the tax payment for the individual farm with livestock can be expressed in the formula below, where T is the CO_2-eq tax of, for example, DKK 750 per tonne of CO_2-eq.

$$\text{Tax payment} = T * E\text{missions from livestock} = T * \left(\sum AD_i * EF_i\right)$$

Activity data is e.g. number of dairy cattle, number of pigs (sows, fattening pigs and piglets) and type of housing. Based on the emissions inventory, there are approx. 250 unique variations for activities (AD) in emissions from digestion and fertiliser management in stables and in storage facilities for livestock and types of housing, each with an individual emissions factor (EF). In the situation where, for example, feed additives become widespread and widely used, this will be reflected in the emissions inventory's ongoing work with emissions factors. Emissions factors will decrease with the introduction of approved technical reduction measures such as feed additives.

Based on the above, the approach to data for calculating the tax can be illustrated as in *Figure 5.1*. The figure is based on the tax on livestock. However, it is the same system that applies to the regulatory basis for fertiliser tax and carbon tax on agricultural land.

Figure 5.1. Data streams used for calculating tax

The farmer self-declares activity data (AD) according to common practice in e.g. the fertiliser accounts and the livestock register on livestock and type of housing (number of cattle/pigs, type (dairy cattle/fattening pigs).

The Danish Customs and Tax Administration calculates the tax based on the calculation of the farm-related inventory of emissions from item 3 and creates a levy for the farm (Farmer from item 1). The Danish Customs and Tax Administration handles any complaints about calculation and collection.

Activity data in the fertiliser accounts is controlled and managed by the Danish Agricultural Agency (data owner). The data owner also fulfils other administrative law obligations in relation to activity data (e.g. corrections of activity data, declaration of data, data rectification and complaint handling in connection with the activity data).

The Danish Customs and Tax Administration multiplies emissions factors (EF) and activity data (cattle/pigs, type (dairy/fattening pigs) and type of housing) via a data link to activity data. The owners of the activity data send a statement of the farms subject to tax to the Danish Customs and Tax Administration.

Base deduction in tax

The base deduction in the tax on livestock is organised according to the same criteria as for the tax, i.e. with variations based on weight, breed, stable types, etc., *see Appendix 7.6*. This means, for example, that dairy cows receive a base deduction that is higher than the deduction for beef cattle.

De minimis limits in tax

The starting point is that all livestock included in the emissions inventory must be taxed based on the emissions factors from the emissions inventory. In addition to cattle and pigs, the emissions inventory includes chickens, pheasants, ducks, mink, sheep, goats, horses, deer, lambs and ostriches.

When introducing a tax, de minimis thresholds will need to be set for when a farm should be taxed. The introduction of de minimis thresholds means that not all livestock are included in the tax base, which may constitute state aid. For a de minimis threshold to be in line with EU state aid rules, there must be proportionality between the administrative burden that is reduced by not including all animals and the amount of emissions that will be reduced. The assessment is that de minimis thresholds can be established within the framework of EU state aid rules, with the final assessment depending on their design. There are already de minimis limits in the fertiliser accounts for how large a farm must be (measured in e.g. produced kg nitrogen) to be registered in the fertiliser accounts.

Tax on applied fertiliser

To calculate emissions from fertiliser spread on fields, the emissions inventory uses an average emissions factor for nitrogen of approx. 4.2 kg of CO_2-eq per kg nitrogen spread on fields.

Reducing fertiliser usage in relation to a farmer's nitrogen quota can be used as an instrument in the existing nitrogen regulation. The effect of this is included in *Climate Status and Outlook 2023*. If a tax on applied fertiliser is introduced, it will, all else being equal, displace part of the climate effect of mandatory catch crops and livestock catch crops, which are included in the existing nitrogen regulation. In order to ensure that the climate effect of a tax is additional to the effect of the existing nitrogen regulation, it is assumed that the existing nitrogen regulation is adjusted by, for example, removing reduced fertiliser usage as an instrument in the mandatory catch crops and livestock catch crops. Other things being equal, such an adjustment will increase the costs for the farmer to comply with the nitrogen regulation. The cost of this has not been calculated.

Tax and subsidies for wetland restoration of carbon-rich agricultural land

Unlike activity data on livestock and fertiliser, farms do not self-report the number of hectares of carbon-rich agricultural land. In the emissions inventory, emissions from carbon-rich agricultural land are calculated by an overlap analysis between the carbon map (formerly the Texture14 map, now the Peat 2022 map) and the so-called cultivation maps (IMK maps) of agricultural land used for the payment of agricultural subsidies.

In recommending a tax, the Expert Group assumes that it is possible to create a regulatory basis based on the same overlap analysis. In addition, the structure for the tax on carbon-rich agricultural land is assumed to be the same as for livestock and fertiliser applied to fields, see the figure above.

The Expert Group recommends that farmers are given the opportunity to challenge the carbon map if they have been levied a tax and disagree with the classification of the carbon content of their soil. The farmer must be able to have his soil tested by an impartial, state-authorised third party who takes soil samples based on set technical standards, and an accredited laboratory must analyse the soil samples. The Expert Group has noted that AU(DCA) is working on a proposal for how a challenge right of the carbon map at field level can be designed in relation to technical standards (including number of soil samples, location of soil samples in relation to the specified area and possibilities for including measurements of carbon content with drones).

Such a solution would involve financial costs for sampling as well as an increased demand for resources for soil samples. In addition, the solution incurs financial costs in terms of processing time to handle the complaints from farmers.
It can be considered whether a fee should be charged to the farmer if they wish to exercise their right of challenge provision.

If the updates are to be used by the authorities to adjust the tax, the updates from the soil samples must be plotted on a map. AU owns the data in the carbon map. It would be recommended that the authorities and AU work together to ensure that farmers' objections can be updated in the existing carbon map. The Expert Group notes that the basis for emissions from carbon-rich agricultural land is uncertain. Most recently, AU (DCA) has decreased the number of hectares, and towards KF25 an adjustment of the emissions factors is expected. Therefore, it is a prerequisite that the necessary resources are allocated to the area to establish a robust tax base.

It is assumed that the subsidy can be based on an expansion of the appropriation for existing schemes, *see Section 3.1*.

Subsidy for afforestation

The Expert Group has presented a model with private afforestation, which has the lowest public costs (per tonne of CO_2-eq). However, the high recreational value of state afforestation may mean that more funds should be allocated to achieve the same CO_2-eq effect with higher government costs but greater recreational value. The Expert Group therefore recommends that the relevant authorities and political decision-makers ensure an appropriate distribution between private and state-owned forests based on an overall assessment of costs and socio-economic profitability, including consideration of the applicable environmental and nature objectives.

Subsidy scheme financed by agricultural subsidies for reduced fertiliser usage

It is considered possible to implement a subsidy scheme for reduced fertiliser usage from 2026 if a decision is made before the end of 2024. The scheme could be financed from agricultural subsidies by reducing direct agricultural subsidies (the hectare subsidy). Specifically, the subsidy will be given to farmers to reduce their so-called fertiliser quota. This is described in more detail in *Box 5.1*.

Box 5.1

The fertiliser quota

A farmer's fertiliser quota is the sum of the nitrogen norms for the farmer's fields. The norms are an estimate of the amount of nitrogen that gives the farmer's economically optimal crop yield at the fertiliser level, where the income from the extra yield can just about pay for the extra cost of the nitrogen fertiliser. The norms are estimated by averaging the optimal fertiliser application across farms. The norms are set by a committee led by Aarhus University, with participation from SEGES, the Department of Food and Resource Economics and the Ministry of Food, Agriculture and Fisheries of Denmark, and constitute a central element of the existing nitrogen regulation.

The actual average fertiliser usage by farmers is below the norm. This is because the norm is set as an average of the economically optimal use and sets an upper limit on fertiliser usage. This means that some farmers have an economic optimum for their fertiliser usage that is below average and will, therefore, use less fertiliser than the norm allows. The average fertiliser usage indicates a large spread.

A possible subsidy scheme is based on the existing model for *targeted nitrogen regulation*, which will have to be adjusted in a number of areas, as compensation for reduced fertiliser quotas has not previously been given.

The subsidy scheme is expected to be offered as a so-called bio scheme. Like other eco-schemes, the scheme will work by allowing farmers to apply for subsidies for reduced fertiliser usage at the beginning of the year (early February to late April). The Danish Agricultural Agency will be responsible for development, case management, payment of subsidies, control of the scheme, etc. The introduction of an eco-scheme requires funding and the approval of the EU Commission. A new eco-scheme will have to be included in the Danish strategic plan for the implementation of agricultural subsidies, which is covered by the Agricultural Agreement. Among other things, the EU Commission will have to accept that the quota reduction is compensated.

EU rules for agricultural subsidies state that losses or additional costs can be compensated for and that the compensation rate can be set according to the average marginal cost of implementing the desired reductions. This is described in more detail in *Box 5.2*. The calculation of the subsidy rate must be carried out or verified by an institution independent of the ministry. In Denmark, the University of Copenhagen (IFRO) handles this task.

Box 5.2

Determination of CAP-funded subsidy

The calculation of subsidies is stipulated in the EU rules for agricultural subsidies. It must be carried out or verified by a knowledge institution independent of the ministry, which is why IFRO handles the calculations in Denmark.

EU rules for agricultural subsidies state that farmers can be compensated for the loss or extra cost incurred by complying with the subsidy scheme's requirements. The calculation may also take into account the objectives to be achieved by the scheme, which, depending on the specific scheme, may allow for a more marginal consideration, *see (EU) 2021/2115, Article 31(7)(b) for eco-schemes and Article 71(4) for Pillar II*.

The compensation rate can be set according to the marginal cost of realising the desired reductions. IFRO's calculation will be based on the costs and losses incurred by farmers to meet a given target. Here, it is assumed that the farmers first use the transition elements with the lowest costs, then the elements with the second lowest costs, and so on until the costs correspond to the farmers' average marginal costs of reaching the target.

By taking marginal costs, rather than average costs, as a starting point when setting a compensation rate, the possibility of achieving the set goals increases. Such an approach is currently used to determine the compensation rate in the targeted nitrogen regulation, where the specific approach has been approved by the European Commission.

When introducing regulation for reduced fertiliser usage, interaction challenges with other environmental subsidy schemes will need to be addressed. For example, it is currently unclear whether ecologists can be included in the subsidy scheme while receiving a conversion subsidy. The Agricultural Agreement states that the targeted regulation will be replaced by a new and more cost-effective nitrogen regulation model from 2026.

Subsidies for biochar by pyrolysis

It is estimated that there is currently no sufficient economic incentive for pyrolysis producers and farmers to produce biochar by pyrolysis or store biochar. The Expert

Group suggests that inspiration be sought from the subsidies for capturing and storing CO_2 (CCS), where subsidies are given per stored tonne of CO_2. This means that there is a competitive subsidy tender that companies can bid on. The winning company will be responsible for the entire supply chain. The sale of private carbon credits and the fertiliser value of biochar can potentially improve the profitability of biochar. There is currently no experience with subsidy schemes for greenhouse gas reductions from biochar.

According to the IPCC's guidelines, greenhouse gas reductions from biochar are only recognised when biochar is stored in agricultural land. Therefore, the CO_2 effect of the subsidy will only be certain if it is allocated to the storage of biochar in agricultural land. This applies regardless of whether biochar is produced domestically or imported. Danish production of biochar that is exported will be included in the calculation in the recipient country. Support for biochar should, therefore, be conditional on storage in Danish soil. The subsidy rate for biochar should reflect the emissions factor of the biochar, including any variations in relation to the carbon content of the stored biochar. The carbon content depends, among other things, on the biomass used to produce biochar. The exact design of a possible subsidy scheme must be clarified in further work. Establishing an aid scheme for storing biochar in agricultural land will involve the development of a new aid model, which will need to be authorised under the EU State Aid Guidelines.

In addition, clarification of a number of environmental issues, agronomic consequences and determination of climate effects of storing biochar in agricultural land is ongoing. Among other things, research results on the amount of environmentally harmful substances in biochar are still pending. The inclusion of climate effects in the national emissions inventory and Climate Status and Outlook will await methodology development for the emissions factor for biochar, *see Section 7.5*.

It is assumed that there is clarity on the regulatory framework, including environmental regulation, the emissions factor and the subsidy scheme for storing biochar in agricultural land in 2027.

Implementation time

The Expert Group has noted that, in connection with the implementation of the CO_2-eq regulation models, there will generally be a need to strengthen the control and quality of the data sources for activity data from the existing environmental, food and regulation, increase the incentives for correct registration in existing registers and adjust the administrative setup if the data sources are to be able to be used as assumed above and be used as a basis for variations in a taxation and subsidy basis. In the assessment, it is assumed that authorities with responsibility for the data used, e.g. from existing environmental and food legislation, are also generally responsible for administrative law obligations, including the declaration process and data corrections. The Ministry of Food, Agriculture, and Fisheries expects that the Danish Agricultural Agency can handle an improvement in data quality for livestock (including stables) in 2 to 4 years if the necessary administrative resources are provided. It has not been possible to estimate the timeframe for improving data quality and control on fertiliser application and providing data on the use of technologies, but it is assumed that this is feasible.

It is expected that the Danish Customs and Tax Administration can develop and implement systems for calculating and collecting the taxes. The Ministry of Climate, Energy and Utilities issues an executive order setting emissions factors for the purpose of applying the taxable base. When setting emissions factors, consideration should be given to updating them as new knowledge is obtained about, for example, technologies, minor adjustments to existing emissions factors, and how often the emissions factors and, thus, the tax base are adjusted. In addition, a data connection between the systems of the Danish Agricultural Agency and the Danish Customs and Tax Administration will need to be developed and implemented. Overall, the Expert Group's models will result in administrative costs for affected authorities. Subject to the specific content of the tax model, it is estimated that the implementation of the calculation engine, collection module and data connection between the systems in, for example, the Danish Agricultural Agency and the Danish Customs and Tax Administration will take 2-4 years. It is estimated that legislative proposals can be submitted 12-15 months after a political agreement has been reached.

In its calculations, the Expert Group has assumed that a tax on agricultural greenhouse gas emissions could come into force from 1 January 2027 and be phased in towards 2030.

State aid and other obligations

The tax initiatives, including the aforementioned base deductions per hectare and per animal, together with the other tax and subsidy elements in the Expert Group's models, must be implemented in accordance with EU legal obligations, including state aid rules and other obligations. Once the final model is finalised, it may be necessary to obtain approval of the model under state aid rules or at least discuss any state aid issues with the European Commission.

Main Characteristics of Current Regulation

6

6. Main Characteristics of Current Regulation

The Expert Group's considerations must be seen in the context of the current regulation of greenhouse gas emissions. This chapter describes the current CO_2-eq regulation of agriculture and LULUCF today and in the future.

Today, greenhouse gas emissions are not separately regulated for the agricultural and forestry sector, but environmental regulations, to a large extent, also affect greenhouse gas emissions. Environmental regulation consists mainly of regulation of nitrogen from fertilisers, livestock regulation and incentives via the EU's common agricultural policy.

It also describes international CO_2-eq regulation (Section 6.1) and upcoming EU plans and initiatives (Section 6.3).

6.1 International CO_2-eq Regulation

The international regulation of greenhouse gas emissions from the agriculture and forestry sector is primarily overseen by the EU. In the EU, this is done through the EU's Effort Sharing Regulation, the EU's LULUCF Regulation and the EU's Common Agricultural Policy (CAP).

The Effort Sharing Regulation and the LULUCF Regulation's reduction commitments can basically be realised in two ways: 1) by national reduction measures and 2) by using a variety of flexibility mechanisms. This provides more options that can impact the coherence between the fulfilment of EU commitments and the 70 per cent target as well as the climate target for agriculture.

The EU obligations impose certain demands on the need for national reductions. Thus, the connection between fulfilling the EU obligations and the national climate targets depends partly on timing and partly on the reduction efforts in the specific sectors. As the national 70 per cent target is a point target in 2030, and the Effort Sharing Regulation is a budget target for the period 2021-2030, a significant reduction effort early in the period may mean that meeting the EU obligations does not, in isolation, lead to meeting the 70 per cent target. However, it is possible that the fulfilment of the national climate targets, including the 70 per cent target, the climate target for agriculture, and the EU obligations are considered in conjunction, so that all the obligations are fulfilled simultaneously without over- or underfulfilment. If reduction efforts are organised so that all obligations are met simultaneously, the use of flexibility mechanisms can alleviate the need for how speedily reduction efforts are initiated.

6.2 Regulation of Non-Energy-Related Greenhouse Gas Emissions from Agriculture and Forestry

Non-energy-related greenhouse gas emissions from agriculture are not currently regulated. This means, among other things, that they are not covered by the CO_2 tax that was agreed upon in the *Green Tax Reform Agreement* from 2022. However, current environmental regulation has an impact on greenhouse gas emissions, so it can be said that environmental regulation also indirectly regulates a share of the greenhouse gas emissions.

A number of activities in the use of agricultural land determine each farm's impact on both the climate and the environment. These are cycles of carbon, nitrogen (as nitrate, nitrous oxide and ammonia) and phosphorus, where environmental and climate action can have both positive and negative synergies at the same time. Animal digestion is only regulated to a limited extent within current environmental regulation.

Current environmental regulation can be broadly categorised into three categories: i) land use regulation, ii) livestock regulation and iii) the EU's common agricultural policy. These types of regulations are rooted in various EU directives and national regulations, a number of which are aimed at reducing the environmental impact of agricultural production.

Land use regulation affects emissions from fertiliser spread on fields. The regulation focuses primarily on nitrogen emissions. The purpose is to protect the water environment and reduce the risk of oxygen depletion in coastal areas as a consequence of nitrogen leaching from fertiliser usage, thereby contributing to the fulfilment of the EU Nitrates and Water Framework Directives. When nitrogen is spread on fields, some of it turns into nitrous oxide (N_2O), which is a greenhouse gas. Thus, the regulation of fertiliser usage in agriculture has an impact on both climate and environmental goals. Efforts in relation to climate and the environment can therefore be seen in context.

The land use regulation includes a number of initiatives, including so-called catch crop schemes, where farmers can choose between a number of measures to reduce nitrogen leaching. The nitrogen initiative is expected to be increased towards 2027, as agreed in the *Agreement on the Green Transformation of Danish Agriculture* from 2021. A number of initiatives have been launched in the area of nitrogen, *see Section 3.2*.

Livestock regulation affects emissions from fertiliser management, i.e. the storage of slurry in stables, containers and the like. The regulation consists of permits and environmental approvals for these. The aim is to limit pollution from livestock farming, including the use of technologies in relation to ammonia and odour. In addition, the regulation contributes to the fulfilment of a number of EU directives, including the Industrial Emissions Directive, the Habitats Directive and national requirements on odour nuisance, nature conservation, noise impact, dust, etc.

The EU's Common Agricultural Policy (CAP) indirectly affects emissions from a number of production methods through voluntary subsidy schemes. In addition, there are a number of requirements (conditionality requirements) that the farmer must fulfil in order to be eligible to receive the hectare subsidy, which also affects agricultural emissions. This includes requirements that 4 per cent of the farmer's area is made up of non-productive elements (e.g. fallow land). The purpose of agricultural subsidies is to ensure an economically viable agricultural industry that produces safe food within the framework of environmentally sustainable production. In addition to direct agricultural subsidies, agricultural subsidies include both voluntary initiatives and basic requirements in a number of areas. Denmark designs the various subsidy schemes within the overall EU framework, but it must be approved by the European Commission.

6.2.1 Existing nitrogen regulation

Nitrogen regulation in Denmark fulfils obligations arising from a number of EU directives, including the Water Framework Directive, the Nitrates Directive and the Habitats Directive.

The Water Framework Directive obliges EU Member States to create the conditions for good ecological status in coastal waters by 2027. According to the Danish implementation of the directive, this means, among other things, a need to reduce the discharge of nitrogen to coastal waters.

It is currently estimated that the total need for action amounts to approximately 13,000 tonnes of nitrogen reduction. The need for action is very unevenly distributed across the country and is calculated on the country's 108 coastal water catchments. While additional efforts are not needed in some areas of Denmark, very significant reductions are needed in other areas. A new assessment (second opinion) of the need for action will be carried out ahead of the review of the *Agreement on the Green Transformation of Danish Agriculture* of October 2021 (the Agricultural Agreement). The need for action may be adjusted as a result.

There is currently a fertiliser tax of DKK 5 per kg of nitrogen, which farmers can be exempted from by registering in the fertiliser register. Almost all farmers are enrolled in the register and thus do not pay the tax.

Nitrogen initiative

The Agricultural Agreement includes a technical budgeting of the majority of the outstanding reduction needs. The breakdown of these initiatives is *shown in Table 6.1*.

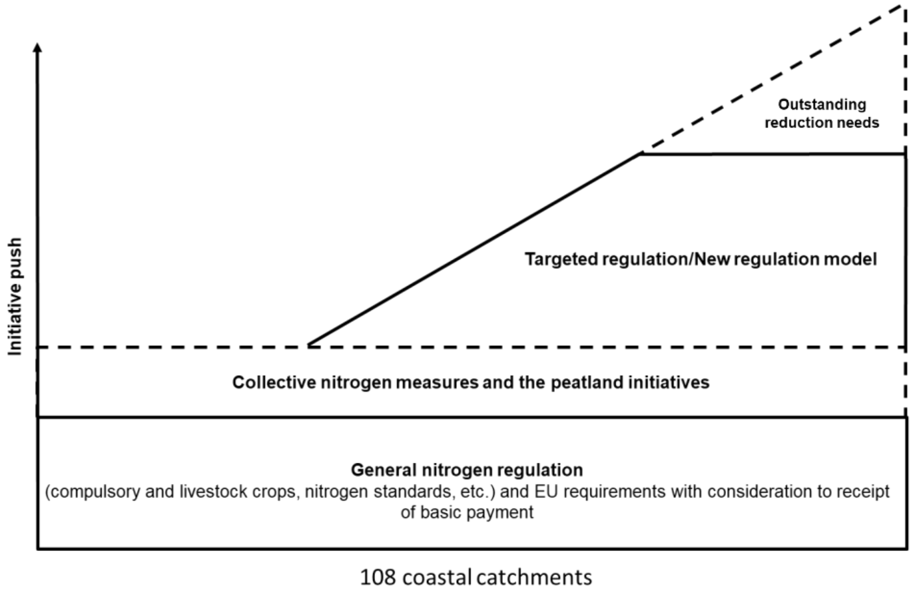
Table 6.1. Technical budgeting of the nitrogen initiative at national level, see *Agreement on Green Transformation of Danish Agriculture*

Initiative	Effect in 2027
EU requirements and other general efforts	2,400
Collective action measures to reduce nitrogen emissions	1,500
Targeted nitrogen regulation/New regulation model	6,500
Remaining effort to be handled on revisit in 23/24	2,600
Total	**13,000**

Source: River Basin Management Plan 2021-2027 (VPIII)

In addition to the initiatives listed in *Table 6.1*, a general basic regulation is implemented. The overall nitrogen regulation is outlined in *Figure 6.1*.

Figure 6.1. Nitrogen regulation



The individual elements of the figure are explained below:

Foundational regulation. The initiatives agreed in the Agricultural Agreement expand the existing general regulation that all farms above a certain size are subject to. The general regulation includes a number of requirements for the establishment of catch crops, restrictions on the possibility of using fertiliser etc. The general regulation follows in particular from the Danish implementation of the EU's Nitrates Directive, as well as EU requirements for good agricultural practice (GAP).

In addition to the general, nationwide regulation, supplementary measures are implemented in areas with additional needs, see the Danish implementation of the Water Framework Directive. These efforts consist of the collective measures to reduce nitrogen emissions and targeted regulation.

Collective measures to reduce nitrogen emissions. With the collective measures, farmers can choose to create wetlands, among other things. With the Agricultural Agreement, it is technically budgeted that the collective measures will achieve a nitrogen reduction of 1,500 tonnes. In the Agricultural Agreement, it is assumed that the collective measures have a climate effect of 0.02 m tonnes of CO_2-eq in 2025 and 0.1 m tonnes of CO_2-eq in 2030, which is included in the *Climate Status and Outlook 2023*.

Targeted nitrogen regulation/New regulation model. The existing targeted regulation ensures annual nitrogen reductions. According to the Agricultural Agreement, the targeted regulation will be replaced by a new and more cost-effective nitrogen regulation model from 2026. Both the existing and future nitrogen regulation models relate specifically to fertiliser applied to fields and field operations and are discussed in more detail below. The Agricultural Agreement assumes that targeted regulation has a climate effect of 0.29 m tonnes of CO_2-eq in 2025 and 0.54 m tonnes of CO_2-eq in 2030, which is included in the *Climate Status and Outlook 2023*.

Outstanding action needs. With the Agricultural Agreement, no decisions were made on initiatives that could ensure the realisation of the full reduction requirement under the Danish implementation of the Water Framework Directive. The extent of the outstanding effort depends on the above-mentioned assessment of the nitrogen initiative. In connection with the review of the Agricultural Agreement, a decision must be made on how to handle the outstanding need for action.

Targeted nitrogen regulation

As mentioned above, the targeted regulation is only implemented in areas where reductions are needed in accordance with the reduction obligations under the Danish implementation of the River Basin Management Plan.

The existing targeted regulation model has been phased in since 2017 and consists of two parts:

1. A CAP-funded voluntary subsidy scheme
2. A subsequent mandatory requirement if the need for a nitrogen initiative is not met under the voluntary subsidy scheme

Voluntary subsidy scheme. Under the voluntary subsidy scheme, the farmer can apply for a subsidy to establish various transition elements. The transition elements include catch crops, early sowing of winter cereals and set-aside of farmland. The subsidy rate that farmers can receive is calculated across farm types and geographical areas and is set according to the average marginal cost to farmers of using the transition elements to fulfil the need for action within a given coastal water catchment. Each farmer is free to choose how much effort they want to put into the voluntary round. If there are too many applicants in relation to the need for action in an area, the applications are prioritised according to the effect of the transition elements in the water environment.

In addition to the compensated transition elements, farmers can choose to apply the transition element of reduced usage of nitrogen fertiliser. This option is currently not eligible for reimbursement, which means that the option is only used to a limited extent, despite the fact that it is generally considered cost-effective up to a certain level. If the transition element was compensated, it is expected that there would be increased utilisation.

Mandatory catch crop requirement. If the need for action in the individual areas is not met with the voluntary subsidy scheme, a mandatory catch crop requirement is set in the sub-catchment. Farmers who have already contributed under the voluntary subsidy scheme will be credited for this effort when the mandatory requirement is distributed. The farmer is not compensated for fulfilling the mandatory requirement, but can still choose to use the same catch crop alternatives as under the voluntary scheme. The vast majority of the effort is handled in the voluntary subsidy scheme. In 2023, for example, approx. 97 per cent of the effort was handled with the subsidy scheme.

6.2.2 The EU's Effort Sharing Regulation

The Effort Sharing Regulation sets national reduction targets for the sum of emissions from agriculture (excl. LULUCF), road transport, individual heating of buildings, small industrial companies, other waste (not waste incineration) and other minor emissions. The Effort Sharing Regulation includes a reduction target in 2030 compared to 2005 and annual reduction commitments up to 2030. The reduction targets in the agreement are primarily set based on the economic prosperity of the countries, so the most prosperous countries must deliver the largest reductions.

As part of the EU's Fit for 55 package, the Effort Sharing Regulation was revised and the Member States' national reduction targets were generally increased by around 10 percentage points. Denmark's national reduction target was increased from 39 per cent to 50 per cent in 2030 relative to 2005 levels.

Status of fulfilment of the Effort Sharing Regulation's reduction targets

Denmark's outstanding greenhouse gas reductions (so-called total reduction deficit) in the Effort Sharing Regulation over the period 2021-2030 are estimated, with significant uncertainty, to a total of approx. 11.5 m tonnes of CO_2-eq. The shortfall is the total accumulated difference in the period between the annual reduction commitments (the reduction path) and the expected greenhouse gas emissions in the specific years. In comparison, a reduction of greenhouse gases (reduction deficit) in 2030 of 2.5 m tonnes of CO_2-eq is required to meet the national 70 per cent target, which, unlike the target from the Effort Sharing Regulation, is a so-called point target that only concerns emissions in 2030.

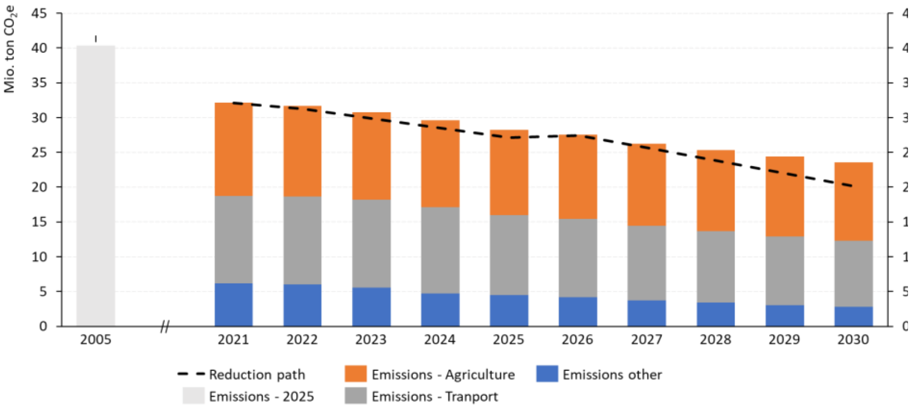
The determination of Denmark's reduction path consists of two main parts:

1) Denmark must reduce its emissions by 50 per cent by 2030 relative to 2005. This corresponds to reducing emissions to 20.2 m tonnes of CO_2-eq by 2030. The point in 2030 is thus the end point of the reduction path. The reductions must be found within the sectors subject to the Effort Sharing Regulation.
2) From 2021 to 2029, a reduction path is defined as an approximately linear progression between a starting point in 2021 and the end point in 2030. 2021 indicates a starting point for Denmark's historical emissions. However, the process is based on different periods for Denmark's historical emissions, which means that the reduction path is only approximately linear.

Reductions in the covered sectors (agriculture (excl. LULUCF), road transport, individual heating of buildings, small industrial activities, other waste (not waste incineration) and other minor emissions) will contribute to the fulfilment of the Effort Sharing Regulation. The majority of emissions, and thus the reduction potential, occur in the agricultural sector (excl. LULUCF) and the transport sector, whereas reductions to meet the 70 per cent target are not limited by sector, *see Figure 6.2*.

Figure 6.2. Status of Denmark's fulfilment of the Effort Sharing targets

m tonnes of CO_2-eq



Note: The reduction path indicates the annual emission allowances. The annual reduction deficit is the difference between emissions and the reduction path.
Source: Ministry of Climate, Energy and Utilities

Denmark has the option of utilising various flexibility mechanisms, *see Box 6.1*. The flexibility mechanisms consist of 1) cancellation of ETS allowances, 2) use of LULUCF credits and 3) purchase of other countries' emission allowances.

Box 6.1

Different flexibility mechanisms

The Effort Sharing Regulation contains three types of flexibility mechanisms that Denmark can use to help fulfil its commitments if sufficient reductions are not achieved.

1) *Cancellation of ETS allowances*. The regulation allows nine Member States, including Denmark, to annually cancel ETS allowances corresponding to a maximum of 2 per cent of the emissions in 2005 from sectors covered by the Effort Sharing Regulation for the fulfilment of the reduction obligation. For Denmark, this is equivalent to a total of 8 m tonnes of CO_2-eq for the period 2021-2030. Denmark has so far committed to cancelling 4 m allowances for the period 2021-2025, but this does not require Denmark to use the cancellation to fulfil the obligation. The use of the cancelled allowances will thus not be associated with an additional government cost. If it is decided to cancel up to an additional 4 m allowances, there will be a government cost depending on the allowance price. Based on the Ministry of Finance's allowance price projections, the cancellation of an additional 4 m allowances for the period 2026-2030 is estimated to result in additional government costs of approx. DKK 3.2 bn as a result of lost auctioning revenue. A decision on further quota cancellation must be made before the end of 2024, with the possibility of an adjustment in 2027.

2) *LULUCF credits*. The regulation allows for the use of national LULUCF credits (under the LULUCF Regulation) based on net removals in the LULUCF sector to fulfil the reduction commitment. In principle, Denmark will be able to use LULUCF credits corresponding to a maximum of approx. 14.6 m tonnes of CO_2-eq over the entire period of 2021-2030. These are limited so that a maximum of approx. 7.3 m tonnes of CO_2-eq can be used in each of the two periods 2021-2025 and 2026-2030, and there is no possibility to transfer credits between the two periods.

Denmark is expected to generate significantly more LULUCF credits in the period 2021-2025 than can be used in the Effort Sharing Regulation in the same period, *see Climate Status and Outlook 23*. The need for reduction under the Effort Sharing Regulation in 2021-2025 is estimated at approx. 4.1 m tonnes of CO_2-eq, which is why it is expected that a maximum of 4.1 m tonnes of CO_2-eq can be covered by LULUCF credits. As credits cannot be transferred between the two periods, excess LULUCF credits will be cancelled if they are not sold to other Member States. In the period 2026-30, Denmark is not expected to fulfil its LULUCF obligation, which means that no LULUCF credits are expected to be generated.

3) *Save, borrow, buy and sell*. In years where emissions are lower than their annual target, Member States can save the surplus and carry over the reduction to later years. There is an upper limit on how much can be saved for later years, but the limit is so high that it is unlikely to be binding for Denmark. In years where greenhouse gas emissions are higher than the annual target, Member States can borrow a limited amount of allocations from the following year. It gives Member States the flexibility to deal with annual fluctuations in emissions due to weather or economic conditions. In addition, Member States can buy and sell allocations from and to other Member States.

The regulation with the Effort Sharing Regulation is binding and contains a penalty mechanism of 8 per cent of the under-fulfilment in a given year. Thus, if the yearly target is underfulfilled by 1 m tonnes of CO_2-eq, an additional obligation of 1.08 m tonnes of CO_2-eq is carried over to the following year. Ultimately, non-compliance with the regulation can result in an infringement case before the European Court of Justice.

6.2.3 EU LULUCF Regulation

The EU LULUCF Regulation sets targets for greenhouse gas emissions and removals from the LULUCF (Land Use, Land Use Change & Forestry) sector, i.e. emissions from primarily fields and forests. The LULUCF Regulation covers emissions from cultivated land, grazing land, wetlands, forests and buildings. Emissions from agriculture, such as emissions from livestock or fertiliser usage, are therefore not covered by the LULUCF Regulation. As part of the EU's Fit for 55 package, the LULUCF Regulation has been revised so that the regulation's commitments are divided into two periods:

1. In the period 2021-2025, Denmark must ensure that the carbon balance in the LULUCF sector does not deteriorate.[36]
2. In the period 2026-2030, Denmark must comply with two separate obligations: 1) net emissions in the LULUCF sector must be reduced by 0.4 m tonnes of CO_2-eq in 2030 compared to the average level of the reference period 2016-2018, 2) meet a national budget target for 2026-2029[37], set by the Commission in 2025 based on the latest emissions inventory.

The two commitment periods of the LULUCF Regulation (2021-2025 and 2026-2029) are budget targets. With budget targets, there are less stringent requirements for when the reduction takes place, although timing still matters. For example, a permanent reduction of 1 m tonnes of CO_2-eq from 2026 to 2029 would result in a total reduction of 4 m tonnes of CO_2-eq. In contrast, a reduction of 1 m tonnes in 2029 would only contribute 1 m tonnes of CO_2-eq to the target.

Status of fulfilment of the LULUCF Regulation's reduction targets

Denmark is estimated to exceed the target in the LULUCF Regulation for the period 2021-25. The budget target for 2026-2029 is finalised in 2025 based on the latest

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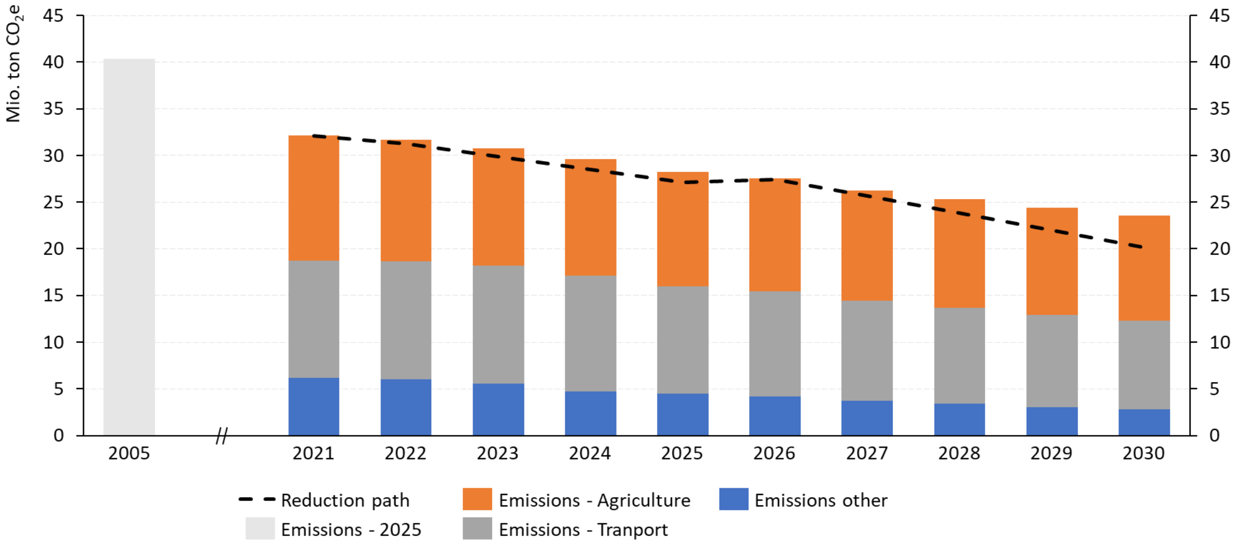
[36] There is no requirement for additional uptake from the sector, but the sector must as a minimum maintain the level of carbon sequestration, as defined by specific accounting rules.

[37] The budget target means that the sector must achieve a set amount of reductions within the period, but there is no requirement for reductions per year.

available historical emissions data. Based on projected emissions, Denmark's reduction deficit is estimated to be around 7.0 m tonnes of CO_2-eq in the period 2026-2029 and around 1.1 m tonnes of CO_2-eq in 2030, *see Figure 6.3*.

Figure 6.3. Status of Denmark's fulfilment of LULUCF commitments



Note: The dotted line for the budget target 2026-2029 indicates the maximum emissions Denmark may have in the period to fulfil the reduction obligation in the LULUCF Regulation. The difference between the dotted line and the line indicating net emissions is the reduction shortfall, which is estimated at 7.0 m tonnes of CO_2-eq for 2026-2029. The 2030 reduction target specifies the maximum amount of emissions Denmark may have in 2030. The difference between net emissions in 2030 and the reduction target in 2030 is the reduction deficit of 1.1 m tonnes.
Source: Denmark's Climate Status and Outlook 2023 and own calculations

From 2021 to 2030, net forest uptake is estimated to be reduced by approx. 2 m tonnes of CO_2 annually relative to the average net forest uptake since 1990. The projected decrease in net forest uptake is a driving factor in the development of the estimated total LULUCF net emissions towards 2030. In addition, carbon-rich agricultural land account for about 90 per cent of the LULUCF sector's gross emissions in 2030. There is a high degree of uncertainty associated with the projection of greenhouse gas emissions from the LULUCF sector.

The EU commitment is formally set as a net uptake target for the EU of 310 m tonnes of CO_2-eq in the LULUCF sector in 2030. This corresponds to an increased uptake of approx. 42 m tonnes of CO_2-eq compared to the average annual uptake for 2016-2018 for the entire EU. The total EU reduction burden is distributed among the member states so that each Member State is allocated a reduction proportional to its share of the EU's total LULUCF area.

The EU obligations for the 2026-29 and 2030 periods must be met separately, with no possibility of transferring over- or underfulfilment between the two periods. The budget target for the entire period 2026-29 can formally be met if emissions are significantly reduced in 2029, even if nothing happens in the years 2026-28. On the other hand, only reductions in 2030 have an impact on whether the 2030 reduction target is met.

Denmark has the option of using various flexibility mechanisms to fulfil its LULUCF commitments, *see Box 6.2*. The flexibility mechanisms consist of 1) cancellation of emission allowances in the Effort Sharing Regulation, 2) purchase of other Member States' LULUCF credits and 3) land use flexibilities.

Box 6.2

Different flexibility mechanisms to fulfil LULUCF commitments

The LULUCF Regulation contains three types of flexibility mechanisms that Denmark can use to help fulfil its commitments.

1) *Flexibility with the Effort Sharing Regulation*: If a Member State does not comply with one or both obligations of the LULUCF Regulation, the obligation can be fulfilled through the cancellation of emission allowances in the Effort Sharing Regulation. The flexibility can be used within each commitment period, but cannot be used to, for example, cover a deficit in the period 2026-2030 by cancelling rights from the period 2021-2025.

2) *Trading of credits*: Member States can buy and sell LULUCF credits from and to other Member States, subject to their availability. After each commitment period, a Member State gains access to an amount of LULUCF credits corresponding to its possible overachievement of its national commitments, which may incentivise Member States to over-implement their own commitments. It is uncertain to what extent LULUCF credits will be available after the end of the commitment period and at what price they will be traded.

3) *Flexibility for land use*: Denmark has access to a limited compensation for a potential shortfall in the period 2026-2030 of 0.05 m tonnes of CO_2-eq, provided that the EU meets its overall target for the LULUCF sector of 310 m tonnes CO_2-eq in 2030. Member States have access to a similar compensation mechanism for the period 2021-2025, which in practice is not relevant for Denmark for accounting reasons.

The LULUCF Regulation is binding and contains a penalty mechanism of 8 per cent of the underfulfilment in the budget period 2026-2029. If the target for the budget period is underfulfilled by 1 m tonnes of CO_2-eq, the emission allowances in the next budget period will be reduced by 1.08 m tonnes of CO_2-eq. For example, if Denmark underachieves the point target in 2030 by 1 tonnes of reductions and at the same time has underfulfilled the commitment in the budget period 2026-2029 by 1 m tonnes, Denmark will have a total result in 2030 of missing reductions of 2.08 m tonnes of CO_2-eq, which will be transferred to the commitment after 2030. In preparing the post-2030 commitment, the Commission is obliged to take into account possible deficits for 2030 when presenting proposals for the post-2030 period. In extreme cases, non-compliance with the regulation may result in an infringement case before the European Court of Justice.

The Expert Group's model 1 fulfils both the LULUCF Regulation's budget target from 2026-2029 and the point target in 2030, *see Table 6.2*. Model 2 fulfils the budget target and approximates the point target, while the reduction deficits to meet the targets are significant in model 3.

It should be noted that all models assume the use of LULUCF credits in the period 2021-2025 to fulfil the Effort Sharing Regulation, as well as up to EUR 8 m in LULUCF credits for the period 2021-2025. ETS allowance cancellations over the entire period 2021-2030 correspond to Denmark's total opportunities for allowance cancellation. It is assumed that the use of LULUCF credits is prioritised before the use of ETS allowance cancellations.

Denmark has already committed to and paid for the cancellation of allowances corresponding to 4 m tonnes of CO_2-eq for the period 2021-2025. The use of the cancelled allowances will thus not be associated with an additional government cost. If it is decided to cancel up to an additional 4 m allowances, there will be a government cost depending on the allowance price.

In addition, it is assumed that overfulfilment of the Effort Sharing Regulation is used to fulfil the LULUCF commitments in 2026-2029. Finally, it is assumed that LULUCF credits and ETS allowance cancellations are used chronologically (i.e. as soon as and if they can fill a reduction need that is not covered by domestic reductions).

If no ETS allowance cancellations are used, none of the models fulfil the LULUCF commitments, while the Effort Sharing Regulation is fulfilled in models 1 and 2, *see Table 6.2*.

Table 6.2. Fulfilment of LULUCF commitments in the Expert Group's models

	LULUCF, 2026-29		LULUCF 2030		The Effort Sharing Regulation, 2021-2030	
	Outstanding reduction deficit (m t of CO_2-eq)	Fulfilment (per cent)	Outstanding reduction deficit (m t of CO_2-eq)	Fulfilment (per cent)	Outstanding reduction deficit (m t of CO_2-eq)	Fulfilment (per cent)
When using 8 m ETS allowance cancellations						
Model 1	0	100	0	100	0	100
Model 2a	0	100	0	100	0	100
Model 3a	0.58	92	0.00	100	0	100
Without the use of ETS allowance cancellations						
Model 1	5.88	17	0.74	35	0	100
Model 2a	6.46	8	0.54	53	1.00	94
Model 3a	5.60	21	0.00	100	2.99	79

Source: Own calculations

6.2.4 The EU's Common Agricultural Policy (CAP)

The aim of the EU's Common Agricultural Policy is to ensure an economically viable agricultural industry[38] that produces safe food within the framework of environmentally sustainable production. The Common Agricultural Policy finances several voluntary initiatives in areas such as the environment, climate, and biodiversity and sets basic requirements for receiving the subsidy. The Common Agricultural Policy (CAP) provides the framework for EU countries' agricultural policies and is set for

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[38] https://www.eu.dk/da/dokumenter/traktater/traktaten-euf/tredje-del/afsnit-iii/artikel-39

the period 2023-2027. A new framework for the Common Agricultural Policy is expected for the period from 2028, presumably corresponding to the period of the next EU budget period (MFF).

Agricultural subsidies consist of a so-called Pillar I and Pillar II. Pillar I is fully EU-funded and includes direct agricultural support, coupled production-linked support and eco-schemes, where support is provided for agricultural practices with a focus on the environment, climate, animal welfare, etc. Pillar II is co-financed between the EU and each Member State. Pillar II provides, for example, investment aid aimed at, among other things, climate and the environment, but also with the possibility of investments for the modernisation of agricultural holdings, start-up aid for young farmers and support for local action groups. For each country, the distribution between the pillars is regulated by EU rules.

In the Danish implementation, approx. 90 per cent of the funds are in Pillar I. Member States are required to earmark the equivalent of at least 25 per cent of Pillar I funds for so-called green eco-schemes in the period 2023-2027 and 35 per cent of Pillar II funds for green purposes, including animal welfare. In addition, a portion of the funds is required to be used for young farmers and to support local action groups. Member States have the possibility to transfer funds between pillars and offset any over-fulfilment for green purposes in Pillar II against the earmarking for eco-schemes in Pillar I. If Member States do not fulfil the requirements, earmarked EU funds could ultimately be lost.

The direct agricultural subsidy amounts to approx. DKK 1,900 per hectare and is granted on the condition that a number of requirements are met. This includes statutory EU management requirements on the environment, animal welfare, etc., in sectoral legislation, as well as requirements for good agricultural practice in pre-defined areas. Together, these requirements are termed conditionality and, together with any other relevant national legal requirements, constitute the basic requirements for the farmer that cannot be compensated through voluntary schemes. The starting point is that the funds spent on voluntary schemes in the CAP (such as eco-schemes) must be used to achieve additional effects. However, under certain conditions, subsidies may be granted for up to two years after a requirement has become applicable to a farmer.

The CAP rules also set limits on the amount of compensation for measures within the voluntary schemes, which must also be verified by an independent institution. In Denmark, it is the Department of Food and Resource Economics (IFRO) at the University of Copenhagen that usually verifies. In the case of compensation for changes in agricultural practices, e.g. to deliver a greater environmental or climate effort on agricultural land, the compensation is calculated based on the calculated *additional* costs (including offsetting of saved costs such as reduction of tax payments) or lost profit that the farmer will experience as a result of the changes in agricultural practices that a given subsidy scheme gives rise to.

No compensation can be granted within the Common Agricultural Policy covering 2021-2027 or the corresponding state aid guidelines for the agricultural sector or the block exemption scheme for the agricultural and forestry sector for e.g. the number of tonnes of CO_2 emissions reduced. On the other hand, a subsidy for investments in changing agricultural practices can be granted, where the subsidy may amount from 20 per cent to 100 per cent of the eligible investment itself. Green technology investments can be subsidised by up to 80 per cent. In the case of in-

vestments that do not increase productivity, such as green investments like disconnecting drains in peatland projects or afforestation, the subsidy can be increased to 100 per cent.[39]
The implementation of the Common Agricultural Policy can therefore support measures that lead to reduced environmental and climate impact when the change in practice occurs. In the Agricultural Agreement from 2021, agricultural support delivers climate and nitrogen effects through some of the basic requirements as well as through the individual subsidy programmes, such as set-aside of carbon-rich agricultural land and targeted regulation (nitrogen).

It is possible to apply annually for the European Commission's approval of changes to the CAP plan as well as three additional times in the period 2023-2027.

The Expert Group's considerations on the use of agricultural subsidies in interaction with overall models for more uniform CO_2-eq regulation in agriculture and forestry are presented in *Chapter 2.*

6.3 Upcoming EU Plans and Initiatives

The Expert Group's work on this final report has run in parallel with discussions in the EU on future initiatives. Future international and national regulation must be integrated.

6.3.1 An ETS for the agriculture and food sector

In Q1 2024, the European Commission is expected to present a communication on a new EU climate target for 2040 and a new EU climate architecture beyond 2030. In the spring of 2023, the Commission launched a public consultation seeking views on the possibility of pricing greenhouse gases from the agricultural sector, including through an emissions trading system. The European Commission has not finalised whether it will propose such a solution.

In November 2023, a report was published by the consultancy Trinomics[40], which was commissioned by the European Commission to investigate the possibilities of introducing an emissions trading system for the agricultural and food sector. The report is exploratory and does not contain clear recommendations, but highlights a number of issues including possible ways to address them. This includes how broadly the system should cover, which emissions are included, the risk of CO_2-eq leakage and the integration of carbon capture. In particular, the report frames a discussion on whether the quota obligation should be imposed on farms, producers of feed and fertilisers ("upstream"), or food companies such as slaughterhouses and dairies ("downstream").

The regulatory framework for subsidies and taxes outlined in this report will contribute to the European Commission's work on a regulatory framework for an ETS in the agricultural and food sector. Among other things, the Expert Group's proposal for a

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[39] It is a prerequisite for support under the agricultural subsidy that the subsidised product is listed in Annex 1 of the EU Treaty on agricultural products (Treaty on the Functioning of the European Union (2016/C202/01)).

[40] *Pricing agricultural emissions and rewarding climate action in the agri-food value chain*, Trinomics.

regulatory basis proposes to use several of the registers used in Denmark in connection with agricultural subsidies, which are registers that are used across the Member States. There is therefore reason to believe that the Expert Group's regulatory framework could also be implemented in other Member States.

The Danish government has decided to work for the expansion of emissions trading in the EU to as many sectors as possible, including the introduction of an emissions trading system for the agricultural sector after 2030.

On this basis, Denmark has proposed that, as far as possible, pan-European regulation of agricultural emissions and removals should be introduced through an EU common agricultural pillar. With the proposal, emissions and removals from agriculture and agriculture-related LULUCF will be integrated so that all agricultural emissions are covered and regulated through emissions trading. It will increase farmers' incentives for reductions. With one overall EU reduction commitment for agriculture, which is realised through emissions trading, it may be natural that nationally differentiated reduction targets are abolished. Concrete adjustments to national regulation must be examined as international regulation is concretised, decided upon and implemented. A future national climate tax for Danish agriculture will have to be seen in relation to a possible future EU ETS for agriculture, just as there are areas within industry where the tax is seen in the context of the EU ETS.

6.3.2 New separate emissions trading system - ETS 2

In 2023, EU Member States and the European Parliament reached a final agreement on a new separate EU Emissions Trading System (ETS2) for CO_2 emissions from fossil fuels used for road transport, internal transport and heating and cooling of buildings in the non-agricultural sector.

The purpose of ETS2 is to increase and standardise the economic incentive to reduce CO_2 emissions from road transport and buildings across the EU, and to support the fulfilment of EU climate targets. The sectors in ETS2 must reduce greenhouse gas emissions by a total of 43 per cent in 2030 in the EU relative to 2005 levels. ETS2 will operate separately from ETS1 with an expected allowance price of approx. DKK 403 per tonne of CO_2 in 2030 according to the Commission, relative to an estimated allowance price in ETS1 of approx. DKK 806 per tonne in 2030. The reductions resulting from ETS2 are all expected to contribute to Denmark's fulfilment of the Effort Sharing Regulation. The main elements of ETS2 are summarised in *Box 6.3*.

Box 6.3

The main elements of ETS2

- **Scope**: CO_2 emissions from fossil fuels in road transport, commercial/institutional buildings, heating and cooling of buildings, cogeneration and heating installations producing heat for commercial/institutional buildings and households, and emissions from industry and heat production below 20 MW (not included in ETS1).
- **Operators in ETS2:** (excluding the use of options) include petrol and diesel fuel distributors, small heat and power plants below 20 MW (not included in ETS1), and gas, coal and oil distributors supplying fuels for domestic and commercial space heating.
- **Reduction target**: The sectors in ETS2 must reduce greenhouse gas emissions by a total of 43 per cent in 2030 in the EU relative to 2005 levels.

- **Emission permit and monitoring from 2025**: In ETS2, operators must have a greenhouse gas emission permit, which is obtained by applying to the Danish Energy Agency. In addition, operators will be subject to monitoring, verification and reporting (MRV) obligations from 2025.
- **Allowance payment from 2027**: Start buying/selling allowances from 2027.

6.3.3 Carbon removal certification framework

On 30 November 2022, the European Commission presented a proposal for a voluntary EU certification framework for carbon removal. The main objective is to create a better methodological basis for developing credible certificates for activities that remove carbon from the atmosphere, including in the agriculture and forestry sector.

The proposal could potentially contribute to increased financial incentives for e.g. rewetting of carbon-rich agricultural land or ploughing of biochar into agricultural land as a result of the sale of certificates, and in that case could contribute to Denmark's LULUCF commitments. However, it is not possible to estimate how many farmers will join the scheme. Furthermore, the concrete methodologies for the certificates are not expected to be developed until 2030, so a potential climate impact is likely to materialise only after that. It is therefore not expected to have an impact on the Expert Group's models for regulating carbon emissions from carbon-rich agricultural land.

The EU certification framework does not formally limit the possibility of introducing national regulation. For example, a political decision could potentially be made to introduce a negative tax on an activity that could also potentially be certified voluntarily under the certification framework. In that case, there will be no question of double regulation, as any certification is voluntary and not with a view to complying with legal requirements. It should be noted that it is also possible today for operators to apply for certification through similar private schemes. A possible market for climate credits has not been taken into account in the Expert Group's models.

6.4 The EU's Common Agricultural Policy (CAP) and the Expert Group's Models

The terms of reference state that "*The second report will also assess the advantages and disadvantages of a regulatory solution for the agricultural sector, a subsidy model for EU agricultural support and a CO_2-eq tax for this sector or a combination of these, as well as possible measures for cost-effective regulation of agriculture that address CO_2-eq emissions and other externalities, including, e.g. environment and health*".

The Common Agricultural Policy (CAP) is part of the EU countries' policy and regulation in the field of agriculture, *see Section 6.2*. Denmark's implementation of the CAP and the use of CAP funds have been agreed in connection with the Agricultural Agreement and are approved by the EU Commission in the Danish CAP plan 2023-2027. New schemes or changes to existing ones in the CAP plan must be approved by the European Commission.

However, it is not the task of the Expert Group to come up with a model for a revised CAP plan or future CAP plans. However, based on the terms of reference, and in consideration of the principle in the Danish Climate Act of supporting the cheapest socio-economic solution for Denmark, the Expert Group has adopted a principle that tax and subsidy models must not lead to a significant loss in the possibility of securing EU funds.

The EU's Common Agricultural Policy, CAP, is designed to support the green transition of the agricultural and food sector. With the CAP funds and the measures that can be implemented under the CAP, it is basically possible to support a wide range of voluntary agricultural activities and technological measures, including relatively expensive measures such as storage and fertiliser management, as well as feed additives. Other possibilities are via the CAP, such as providing investment aid for environmental and climate technologies in stables etc., including increasing the current subsidy rates for such investments. As a starting point, it is also expected to be possible to provide investment aid for the establishment of pyrolysis plants in the CAP, but the investment volume for this may be challenged due to the various considerations that the CAP must deliver on.

A tax on production factors, such as livestock, will affect the production mix and the contribution margin from agricultural production. Since the CAP subsidy for activity-based measures is often calculated based on the loss compared to a corresponding production without this activity, a tax could parallel shift the income from the reference. This can reduce the maximum subsidy on certain schemes. Depending on the scale, this may create a need to reallocate CAP funds.

One point to note when utilising CAP funds is that the funds are generally implemented through voluntary schemes. Thus, farmers must be sufficiently incentivised to apply for the schemes. However, under certain conditions, it is possible to grant support for up to 24 months after a national requirement has entered into force if the requirement goes beyond the corresponding minimum requirements set out in EU law. Depending on the chosen models and requirements, the CAP will, for example, be able to mitigate the cost for farmers, either through a voluntary subsidy scheme until it becomes a requirement, such as a tent covering with floating layers, or through subsidies for up to 24 months after the requirement is made on the use of climate control agents as feed additives.

Development, establishment, IT setup, negotiations with the European Commission and approval of new subsidy schemes will take around 1-1.5 years, and this work and subsequent administration and control is associated with increased costs. Experience has shown that the schemes that achieve the best response are productive schemes where the requirements of the subsidy scheme can be met in connection with continued agricultural production. In the longer term, the tax models will also affect subsidy schemes under an upcoming CAP in the next period 2028-2034.

The Expert Group notes that the establishment of a climate tax in agriculture will affect the currently agreed and approved implementation of the CAP in Denmark. This includes an expectation that subsidy rates will need to be recalculated and that new and different schemes will need to be developed under the CAP, partly to respect the EU requirement for green earmarking and partly to repatriate the funds under the CAP. However, there are several options for establishing increased or new subsidies that can support and incentivise climate action in agriculture. Thus, the models are assessed to allow for continued utilisation of CAP funds.

Appendices

7

7.1 Terms of Reference for the Green Tax Reform

This chapter reiterates the terms of reference and additional terms of reference.

Purpose and background

The agreement on Green Tax Reform reached between the Government (Social Democrats), the Left Party, the Radical Left Party, the Socialist People's Party and the Conservative People's Party on 8 December 2020 states that a CO_2-eq tax should be a key instrument for achieving the 70 per cent target, taking into account the guiding principles of the Danish Climate Act, including sustainable business development and Danish competitiveness, sound public finances and employment, a strong welfare society, cohesion and social balance, and thus real CO_2-eq reductions (minimising CO_2-eq leakage) and without overall job losses abroad.

In the short term, taking the first and essential steps towards a more uniform CO_2 tax is possible. However, in a number of areas, appropriate tax models will require further development, and EU legal, administrative and implementation issues will need to be examined.

The government and the parties to the agreement have therefore agreed to implement the green tax reform in two phases. The first phase will focus on adjustments within the existing tax system as well as extensions to well-defined areas. The second phase will set the framework for a uniform CO_2-eq tax.

It is the ambition of the parties to the agreement that in 2030, Denmark will have a uniform CO_2-eq tax taking into account leakage effects, etc.

Tax structure

A uniform CO_2-eq tax on all emissions is the most cost-effective way to ensure that the 70 per cent target is met, as it sets a uniform price for the emission of greenhouse gas equivalents, with which the reductions across sectors take place where they are cheapest.

Danish CO_2 emissions from fossil fuels are currently taxed with a combination of climate and energy taxes. In addition, parts of industry and large energy and combustion plants are covered by the EU ETS. One of the aims of the tax system is to favour companies in competition with foreign companies. The industries exposed to competition (e.g. mineralogical processes, etc., electricity production and agriculture) therefore pay the lowest energy taxes or are completely exempt from paying energy taxes. Conversely, other businesses and Danish households are taxed more heavily, for example, in connection with heating and their consumption of petrol and diesel.

In addition, the current tax system is characterised by significant variations in the level of taxation depending on the use of fossil fuels.

Under the current tax system, for example, companies pay a much higher tax to heat their buildings than to produce their goods. Taxes on space heating for buildings amount to about DKK 1,300 per tonne of CO_2, while taxes on industrial processes in production amount to about DKK 0-250 per tonne of CO_2. Similarly, subsidies per tonne of CO_2 vary significantly across areas.

Overall, there are high taxes on CO_2 emissions from fossil fuels used for transport and for general heating in houses, etc. Mineralogical processes (cement production etc.) and fossil fuels for electricity production are effectively tax-exempt in the current tax system, but covered by quotas, just as non-energy-related emissions from agriculture, such as methane from cattle or nitrous oxide from fertiliser usage, are also tax-exempt.

However, non-energy agricultural emissions of methane from livestock, nitrous oxide from fertiliser usage and carbon sequestration on agricultural land need to be seen in the context of other regulated nutrient emissions. However, there is currently not a sufficient basis to tax CO_2-eq from all non-energy agricultural emissions.

Thus, restructuring the tax system, including a shift from energy taxation to CO_2, would imply a major restructuring that would have to be seen in conjunction with national subsidy schemes, the EU Energy Taxation Directive, the EU Emissions Trading System Directive and the state aid rules, as well as forthcoming proposals to revise EU climate and energy legislation, including the Energy Taxation Directive and the EU Emissions Trading Scheme Directive, expected in mid-2021. Among other things, the EU Commission is expected to propose strengthening the ETS and models for extending the ETS to additional sectors, including road transport and individual heating of buildings.

Tasks of the Expert Group

The Expert Group will be tasked with developing models for uniform CO_2-eq regulation, including the design of a more uniform CO_2-eq tax. A comprehensive analysis will be provided in the form of sub-reports assessing the impacts of different models for a more uniform CO_2-eq tax. Therefore, the optimal tax structure must be explained in relation to the 70 per cent target, and any derived conditions, including other regulation of other externalities, administrative conditions and barriers to national regulation, must be explicitly stated.

The Expert Group will develop different scenarios that contribute significantly to the 70 per cent target by 2030.

The Expert Group will also consider how to operationalise the guiding principles of the Danish Climate Act. In this context, the Expert Group should present different scenarios that weigh the considerations differently (e.g. weighs carbon leakage high or low). The starting point for all the scenarios should be that they deliver the cheapest socio-economic solution. To the extent that this consideration is departed from, reasons must be given.
The Expert Group should aim for scenarios that are revenue neutral overall and support GDP and labour supply in a socially balanced way. However, the proposals need not be revenue-neutral year-on-year. The Expert Group should also include a proposal where taxes and duties do not increase overall.

In addition to the end goal, different phasing-in scenarios must be created, including sensitivity scenarios with regard to uncertainty associated with the projections. Uncertainties in the phasing-in scenarios need to be taken into account. Among other things, these scenarios should be seen in the context of meeting the 2025 target.

Each scenario should highlight the following:

- Socio-economic: The total socio-economic impact measured by distortion losses both in total and as a share of CO_2-eq reduction (shadow price).

- National economic consequences: Revenue, including tax burden, GDP, labour supply, competitiveness and employment, burden on industries (including detailed industry breakdowns) and households. These consequences must be outlined in the short term (adjustment/transition costs) and structurally.
- Emissions, carbon leakage and environmental impact: CO_2-eq reductions, CO_2-eq leakage, contribution to EU climate targets and other environmental impacts etc. (externalities), if deemed relevant.
- Social balance: Distributional effects, GINI, regional differences, etc.

In addition, the work must consider the fact that technological development is uncertain and that this uncertainty has consequences for the socio-economic costs of meeting the 70 per cent target. As a result, the Expert Group will look at the technological conditions and opportunities across each sector, including the current and future technological options for restructuring.

The work of the Expert Group will ensure that the proposed CO_2-eq regulation best supports the introduction of new resource-saving technologies for both industry and agriculture.

Finally, the Expert Group's proposals must be implementable and take into account regulatory, EU legal, systemic and administrative implications. Consideration must also be given to the proposal's compliance with the energy taxation directive, a possible proposal for a new energy taxation directive, the EU's state aid rules and other relevant international regulation. This must be seen in the light of the fact that the development time and implementation time for initiatives in the tax area, including new tax structures, is considerable.

The work must also be considered in conjunction with other climate policy measures, including current subsidy and agreement schemes etc., and regulation of other environmental impacts (externalities).

It must be ensured that the rescheduling of phase 1, where the rescheduling of the agreed increase in DKK per GJ balanced by CO_2 must be consistent with the long-term solution.

An interim report will be prepared at the end of 2021 in order to be able to convene the contracting parties for discussions at the end of 2021 on the basis of the report. Final reporting will take place in autumn 2022.

Content of the first interim report

The first interim report will describe the overall architecture for a uniform CO_2-eq regulation, including leakage, the link with the 70 per cent target and the EU ETS (current and future) and subsidy schemes, as a basis for working towards the concrete models to be included in the final report. If possible, the first report may also include models for the level of a uniform CO_2-eq tax in 2030.

As a step towards the final architecture for a more uniform CO_2-eq regulation, the first interim report will outline a model for restructuring energy taxation to a more direct tax on CO_2-eq emissions.

With the first phase of a green tax reform, the government and the agreement parties have agreed to increase the energy tax on fossil fuels for businesses by DKK 6 per GJ. This element is expected to lead to reductions in climate-changing emissions of around 0.5 m tonnes of CO_2-eq by 2025.

At the same time, the Expert Group will work towards broadening the tax base to areas that are relatively well-defined, including CO_2 emissions from oil and gas extraction and refining, CO_2 emissions from mineralogical processes etc., fossil fuels for electricity generation and any other CO_2 tax exemptions that the Expert Group considers relevant to include in the first phase.

When restructuring from energy taxation to CO_2 taxation must take into account, among other things, the fossil content (in the form of plastics, etc.) of the waste volumes from waste incineration for district heating, as well as how coal can be phased out in district heating. Furthermore, the impact of the district heating price cap, e.g. on surplus heat from surplus heat suppliers, as well as the space heating tax on individual and collective space heating, needs to be clarified.

The Expert Group must identify appropriate compensation and feed-back mechanisms. The compensation mechanisms can, for example, be in the form of base deductions, subsidies, differentiated rates and/or delayed phasing in of taxes as well as more general compensation measures.

The Expert Group should also assess the interaction between the extended tax base, national subsidy schemes and the European ETS to ensure a uniform CO_2-eq regulation. In particular, whether it would be appropriate to give a deduction in the CO_2-eq tax for allowance payments must also be addressed. In addition, for comparison, CO_2 taxation in other relevant countries can be looked at.

Content of the final report

With the second report, the Expert Group will elucidate models for a more uniform CO_2-eq regulation of all covered emissions. Including different tax levels and phase-in profiles up to 2030 and their economic and practical consequences.

The second report will also assess the advantages and disadvantages of a regulatory solution for the agricultural sector, a subsidy model for EU agricultural support and a CO_2-eq tax for this sector or a combination of these, as well as possible measures for cost-effective regulation of agriculture that address CO_2-eq emissions and other externalities, including, e.g. environment and health. Farm accounts are a prerequisite for CO_2-eq taxes on agriculture. It is assumed that this work will be carried out separately. In addition, an assessment of the advantages and disadvantages of different solutions for emissions from agricultural land and other emissions from LULUCF must be included, which the Expert Group deems relevant to highlight. Future EU legislation in this area, including a potential new approach to regulating the climate impact of agriculture through the revision of the EU's Effort Sharing Regulation and LULUCF Regulation and a separate agricultural pillar in the EU ETS, will be taken into account.

Finally, the Expert Group must come up with proposals for possible ways to construct compensation mechanisms, including, among other things, base deductions, subsidy schemes, differentiated rates, delayed phasing in and connection to existing subsidy schemes, general measures and other possible mechanisms, including European regulation and through the ETS. Compensation mechanisms should also be seen in the light of, among other things, carbon leakage, competitiveness of companies and employment. This should take into account the wide variation in the burden on business both between and within sectors. Proposals for compensation mechanisms must be weighed against other effects thereof.

The work could involve the whole tax and subsidy system, including deductions, exemptions, compensatory measures and grant schemes, whether as a contribution to climate objectives, a financing element, or to address other unintended effects of the reform, such as distributional concerns.

Organisation of the Expert Group

The commission will consist of an external chairman and, in addition, five external members.

In addition, heads of departments from Ministry of Taxation, Ministry of Finance, the Ministry of Climate, Energy and Utilities, Ministry of Industry, Business and Financial Affairs and Ministry for Food, Agriculture and Fisheries participate in the discussions. Heads of departments from other ministries are involved as needed.

The Expert Group will be provided with an independent secretariat composed of officials from the ministries involved and co-chaired by Ministry of Taxation and Ministry of Finance.

In addition, a follow-up group to the Expert Group will be established, consisting of the Confederation of Danish Industry, the Danish Chamber of Commerce, Green Power Denmark, the Danish Agriculture & Food Council, the Danish Trade Union Confederation, Kraka, Concito, Green Transition Denmark, the Danish Council on Climate Change and the Secretariat of the Danish Environmental Economic Council. The follow-up group can function as a useful knowledge bank for the commission. In this way, the follow-up group will be able to contribute current and relevant knowledge to the Expert Group's work on, e.g. the technological development, incentives and economic conditions. In addition, the Expert Group may use external experts, including when ordering external analyses.

Additional terms of reference

In addition to the Expert Group's original terms of reference, the government platform states that "*The climate tax must ensure implementation of the development track and fulfilment of the binding reduction target for the agriculture and forestry sector of 55 per cent to 65 per cent in 2030 compared to 1990. The government will ask the expert committee to present different scenarios for achieving this goal in line with the recommendations the committee presented in connection with the CO2-eq tax on industry, including consideration of counteracting the relocation of production, including international experience and the possibility of applying a CO2-eq tax on end consumption as a possible instrument*".

7.2 Other Land Use Objectives

There are a number of political ambitions and objectives for the areas of Denmark. The government platform includes an ambition to establish 250,000 hectares of forest and to implement 15 nature national parks, *see Table 7.1*.

In addition, in connection with a number of political agreements, agreements have been made on, among other things, an ambition to set aside 100,000 hectares of carbon-rich agricultural land, a doubling of the organic area and an ambition to quadruple renewable energy on land.

Under the EU's auspices, Denmark must contribute to the EU's objective of 30 per cent protected nature, of which 10 per cent is strictly protected.[41] The target is not effort shared, and it has not yet been decided how Denmark's contribution will be realised.
Overall, there are political ambitions for approx. 646,600 hectares, corresponding to 15 per cent of the current area of Denmark. In addition, there are political ambitions and agreements where it is not yet possible to set specific hectare estimates. This applies, for example, to an upcoming law on nature and biodiversity.

Table 7.1. Ambitions and political objectives for Denmark's land area

Political objectives/ambition	Origin	Climate impact	Number of hectares
Doubling the organic area1)	The Agricultural Agreement 2021	It is currently not possible to estimate the climate impact of converting to organic production in *Climate Status and Outlook*.	200,000
250,000 hectares of afforestation2)	Government platform 2022	Afforestation is a relatively long-term transition element. Afforestation towards 2030 will contribute more to climate targets for the period 2040 to 2050 than for the 70 per cent target.	250,000
Set-aside of carbon-rich agricultural land including peripheral land, including extensification of 38,000 hectares3)	The Agricultural Agreement 2021	With wetland restoration, CO_2-eq emissions from cultivated and drained carbon-rich farmland are significantly reduced. Emissions are also reduced by extensification, albeit to a lesser extent.	100,000
Secure framework conditions that enable a quadrupling of renewable energy on land4)	Climate Agreement on Green Power and Heat 2022	The climate impact occurs through displacing fossil fuels.	36,600
Unified Act on Nature and Biodiversity	Government platform 2022 Contribution to EU target	It is currently impossible to estimate the climate impact of implementing the law.	-
Implementation of a minimum of 15 nature national parks	Government platform 2022	No direct climate impact. The indirect climate impact will depend, among other things, on the degree of deforestation, subsequent growth in wood biomass, and land use before and after planting.	-

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[41] In other words, the natural processes are essentially left undisturbed to respect the ecological conditions in the area. Further definition awaits initiative from the European Commission (expected in spring 2024).

Designation of up to three new national parks	Government platform 2022	No direct climate impact.

Note: 1) Announced in the government platform 2019. Number of hectares compared to figures for the organic area in 2018, as this was the most recent figure. 2) Announced in the government platform 2022. The number of hectares is calculated as afforestation in addition to the expected afforestation with the *Climate Status and Outlook 2022* of approx. 20,000 hectares in the period 2025-2030. 3) Announced with the Agricultural Agreement, 2021. 4) Announced with the Climate Agreement on Green Power and Heat, 2022. The number of hectares is calculated by comparing with the RE area in 2021. A doubling of the wind turbine area and a tenfold increase in the solar cell area is assumed.

7.3 Elaboration of Emissions from the Agriculture and Forestry Sector

Emissions from animal production

In 2030, greenhouse gas emissions from animal production are expected to total 6.5 m tonnes of CO_2-eq, *see Table 7.2*.

The vast majority of CO_2-eq emissions from livestock production come from cattle and pigs, which account for 6.1 m tonnes in 2030, corresponding to about 95 per cent of total livestock emissions. Of this, 4.5 m tonnes of CO_2-eq comes from cattle and 1.6 m tonnes of CO_2-eq from pigs.

Emissions from livestock come from two emission sources: 1) digestion (methane/CH_4) and 2) manure handling in stables and storage facilities (methane and nitrous oxide/N_2O), i.e. emissions from manure handling in stables and when manure is stored in e.g. slurry tanks.

Table 7.2. Emissions from animal production

	Digestion (CH_4)	Fertiliser management in stables, storage facilities and fields (CH_4 and N_2O)	Total emissions	Share of emissions from agriculture and forestry
	m tonnes of CO_2-eq in 2030			*Per cent*
Dairy cows	2.4	0.7	3.1	24.7
Other cattle	1.0	0.5	1.5	11.7
Pigs	0.4	1.3	1.6	13.0
Broilers and chickens	0.0*	0.0*	0.0*	0.2
Other livestock	0.2	0.0	0.2	1.7
Indirect emissions	-	0.1	0.1	0.7
Grazing	-	0.0	0.0	0.2
Total	3.9	2.6	6.5	52.3
Total cattle and pigs	3.7	2.4	6.1	49.4

Note: The total does not add up due to rounding. Other livestock includes pheasants, ducks, mink, sheep, goats, horses, deer, lambs and ostriches. Indirect emissions are totalled for all livestock and cover ammonia and NOx emissions that are converted to nitrous oxide in the atmosphere during manure handling. 0.00* does not mean that there are no emissions. It's just less than the 2nd decimal place.
Source: Climate status and Outlook 2023 incl. partial correction for the new map of carbon-rich agricultural land and own calculations.

According to the *Climate Status and Outlook* 2023, emissions of approx. 4.5 m tonnes of CO_2-eq from cattle (divided into dairy cattle and other cattle) are expected in 2030, *see Table 7.3*. The majority of emissions from dairy cattle and other livestock are methane from digestion.

Box 7.1

Net emissions from cattle digestion

Digestion from cattle makes up 70 per cent of the cow's total emissions.

The cow eats carbon in the form of grass and fibre. The feed (grass and fibre) is ruminated in the cow's four stomachs: the rumen, reticulum, omasum, and abomasum. In the cow's rumen, a fermentation process occurs that first converts fibre into hydrogen. The hydrogen is converted to methane by microorganisms in the rumen. Methane is primarily released via the cow's breath and burping. The remaining methane is released after the feed has passed through all four stomachs and is excreted as manure.

The methane emitted by the cow has a CO_2-eq conversion factor of 28 in relation to the carbon that the cow has eaten. Thus, the methane emitted by the cow has a factor 28 higher climate impact per tonne emitted than the carbon in the cow's feed.

Table 7.3. Emissions from dairy cattle and other cattle in 2030

	Methane (CH_4)	Nitrous oxide (N_2O)	Total CO_2-eq	Number of animals
	m tonnes of CO_2-eq in 2030			*m units in 2030*
Dairy cattle	3.0	0.1	3.1	0.5
Digestion	2.4	-	2.4	-
Fertiliser management	0.6	0.1	0.7	-
Other cattle (e.g. suckler cows and veal calves)	1.4	0.1	1.5	1.0
Digestion	1.0	-	1.0	-
Fertiliser management	0.4	0.1	0.5	-
Total	4.4	0.2	4.5	

Note: The total does not add up due to rounding
Source: Climate status and Outlook 2023

In 2030, emissions from pigs are expected to be around 1.6 m tonnes of CO_2-eq in 2030. In *Climate Status and Outlook 2023*, the pig population is expected to consist of approx. 0.9 m yearling sows and approx. 32.9 m piglets, of which approx. 19.3 m will become fattening pigs within the same year, *see Table 7.4*. Approx. 13.6 m pigs are exported, after which emissions are not included in the calculation. The majority of emissions from pigs can be attributed to emissions from fertiliser management in stables and storage facilities.

Table 7.4. Emissions from pigs in 2030

	Methane (CH_4)	Nitrous oxide (N_2O)	Total CO_2-eq	Number of animals
	m tonnes of CO_2-eq in 2030			*m units in 2030*
Piglets	0.2	0.0	0.2	32.9
Digestion	0.1	-	0.1	-
Fertiliser management	0.1	0.0*	0.2	-
Fattening pigs	0.9	0.1	1.0	19.3
Digestion	0.2	-	0.2	-
Fertiliser management	0.7	0.1	0.8	-
Yearling sows	0.4	0.0*	0.4	0.9
Digestion	0.1	-	0.1	-
Fertiliser management	0.3	0.0	0.3	-
Total	1.5	0.2	1.6	

Note: The total does not add up due to rounding. 0.0 means that there are still emissions. It just doesn't show up at the 1st decimal place.
Source: Climate Status and Outlook 2023

It is estimated that in 2030, there will be emissions of approx. 0.3 m tonnes of CO_2-eq from other livestock, *see Table 7.5*. The population of other animals is expected to be around 155 m animals, of which around 134 m are broilers.

Table 7.5. Other livestock in 2030

	Methane (CH_4)	Nitrous oxide (N_2O)	Total CO_2-eq	Number of animals
	m tonnes of CO_2-eq in 2030			*m units in 2030*
Hens	0.002	0.02	0.02	9.8
Broiler chickens	0.002	0.03	0.03	133.6
Pheasants (chicks)	0.002	0.002	0.00	1.0
Pheasants (hens)	0.002	0.002	0.00	0.1
Ducks, geese and turkeys	0.002	0.002	0.00	0.6
Mink	-	0		0.2
Sheep	0.03	0.01	0.04	0.1
Goats	0.002	0.002	0.00	0.0
Horses	0.12	0.05	0.17	0.2
Deer	0.002	0.01	0.01	0.0
Lambs	0.01	0.002	0.01	0.1
Ostriches	0.002	0.002	0.00	0.0
Total	0.2	0.1	0.3	145.7

Note: The total does not add up due to rounding. It should be noted that *Climate Status and Outlook* does not report emissions from other livestock at the above level of detail. Therefore, data from DCE 2021 has been used, which results in a deviation of 0.1 m tonnes of CO_2-eq compared to the emissions projected in the *Climate Status and Outlook 2023.* 0.0 means that there are still emissions. It just doesn't show up at the 1st decimal place.
Source: Report from DCE 2021 and own calculations.

Emissions from carbon-rich agricultural land

Compared to other types of agricultural land, carbon-rich agricultural land has a high content of organic matter (over 6 per cent carbon), which emits CO_2-eq. [42] Emissions from the land can be reduced by setting aside land and rewetting it. Rewetting involves restoring the natural water level. This means that there may be periods of time when the soil is not under water.

Carbon-rich agricultural land is estimated to be around 75,000 hectares in 2030 and is estimated to emit around 2.2 m tonnes of CO_2 in 2030.[43] Carbon-rich agricultural land is expected to account for around 3 per cent of the total agricultural area by 2030.

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[42] Carbon-rich agricultural land is created when organic matter builds up in the soil near the surface due to high water levels. Thus, much of the carbon-rich agricultural land was originally formed in natural wetlands such as bogs and wet meadows. When the land is drained for cultivation, the soil is oxygenated and the carbon decays and is released into the atmosphere, primarily as carbon dioxide (CO_2). If the carbon content is below 6 per cent, the soil is not characterised as carbon-rich.

[43] Based on DCE, Scientific note no. 2024 60 (Gyldenkærne et al., 2024) update of updated map of carbon-rich agricultural land from AU (Beucher et al., 2023)

In the emissions inventory, the 75,000 hectares of carbon-rich agricultural land are divided into four types with different emissions factors. The four types are cultivated land and permanent pasture with carbon contents of 6-12 per cent and greater than 12 per cent, respectively, *see Table 7.6*. Emissions from carbon-rich agricultural land are reduced if land is set-aside for permanent pasture, *see Table 7.6*. However, the biggest reduction is achieved by the rewetting of the areas and their subsequent transition to the area-class wetlands

Following the wetland restoration of carbon-rich agricultural land, there are still limited emissions, which come from a slight increase in methane emissions. If all carbon-rich agricultural land is rewetted, methane emissions are estimated to be 0.4 m tonnes of CO_2-eq in 2030.

Research is ongoing to update the emissions factor from carbon-rich agricultural land, including the relationship between soil carbon content, water levels and emissions. This research may give reason to revise the current assumption that soils with 6-12 per cent carbon have emissions equivalent to half of the soils with >12 per cent carbon. It is expected that the results of the research project will be incorporated into the Climate Status and Outlook for 2025.

Table 7.6. Emissions and hectares of carbon-rich agricultural land

	Area	Emissions per hectare	Total
Area-classes by per cent carbon content	*1,000 hectares, 2030*	*Tonnes of CO_2-eq per hectare, 2030*	*m tonnes of CO_2-eq in 2030*
Cultivated land (agricultural land), 6-12 per cent	16.7	25.2	0.4
Cultivated land (agricultural land), larger than 12 per cent	7.5	50.3	0.4
Permanent grazing land, 6-12 per cent	29.1	18.7	0.5
Permanent grazing land, greater than 12 per cent.	21.7	37.4	0.8
Total	75.0	28.7[1)]	2.2
- of which carbon pool		25.9[1)]	1.9
- of which cultivation		2.8[1)]	0.2

Note: The total does not add up due to rounding. 1) Average of all carbon-rich agricultural land

Source: DCE, Scientific note no. 2024 60 based on correction due to new map for carbon-rich agricultural land (Peat 2022)

Emissions from applied fertiliser and agricultural lime

Emissions from fertilisers applied to fields and agricultural lime can generally be classified into nitrous oxide or CO_2 emissions and are accounted for, *see IPCC guidelines, in the agricultural sector, see Table 7.7*. Nitrous oxide emissions come from nitrogen in fertiliser applied to fields. CO_2 comes from agricultural lime that is applied as part of field operations. The addition of nitrogen and lime is necessary to provide nutrients to the agricultural land to maintain plant production. Emissions from applied fertiliser and liming are thus the primary sources of emissions associated with plant production. Urea is a carbon-based fertiliser that is applied to the field. It represents a very limited amount of the total fertiliser usage.

Table 7.7. Emissions from applied fertiliser and agricultural lime

Sector	Activity	Emission source	Nitrous oxide (N_2O)	Carbon dioxide (CO_2)	Total (CO_2-eq)
			m tonnes of CO_2-eq in 2030		
Agriculture	Fertiliser applied	Artificial fertilisers	0.9		0.9
		Organic fertiliser	0.8		0.8
	Applied agricultural lime[1]	Liming	-	0.2	0.2
	Other fertilisers	Urea		0.0	0.0
		Total	1.7	0.2	1.9

Note: The total does not add up due to rounding

1) Liming is not covered by the current nitrogen regulation.

Source: Climate Status and Outlook 2023 based on the emissions inventory.

Emissions from field operations

Emissions from field operations can be broadly classified into CO_2-eq emissions/removals due to changes in the soil's carbon balance and nitrous oxide emissions from fields.

The largest emission sources for field operations in 2030 are decomposition of plant residues and uptake from carbon sequestration in mineral soils, which are accounted for under agriculture and LULUCF, respectively. The two effects are mutually dependent. Crops initially cause carbon build-up, but when plant residue is left on the field, nitrous oxide is released. Therefore, the net effect on greenhouse gas emissions from field operations depends on the relationship between nitrous oxide emissions and carbon uptake, which depends on crop choice, soil type and quality, among other things.

When crops die and decompose in the field, nitrous oxide emissions are released, which is accounted for under the agricultural sector (decomposition of plant residues). After that some nitrous oxide emissions from the decomposition of biomass that occurs in the soil is released, which is also accounted for under the agricultural inventory (mineralisation).

CO_2-eq emissions/removals in the soil's carbon balance are calculated under the LULUCF sector, *see IPCC guidelines*. The LULUCF sector is an umbrella term for land use and covers both emissions and removals from agricultural land use and the forestry sector.

Emissions and uptake of carbon in mineral soils depend on the interaction between the input of organic matter (plant material and fertiliser) and the decomposition of organic material. The breakdown depends on annual temperature fluctuations. Other things being equal, increased temperatures will cause a greater decomposition of the existing organic material in mineral soil, resulting in net discharge. Conversely, a cooler year will result in a lower decomposition of soil organic matter, thus increasing carbon sequestration and net uptake. Varying weather conditions thus contribute to the overall uncertainty associated with projecting carbon pool changes in mineral soils. This variation can result in both negative and positive emissions. Since 1990, yields and temperature in particular have fluctuated.

However, the CO_2 effect of adding biomass is highly dependent on the soil's carbon content and cultivation history. Increased addition of organic matter to mineral soils, such as through increased plant cover as a result of alternative crop rotation or the use of catch crops, can contribute to more carbon being sequestered in the soil over a long period of time until the soil reaches a new equilibrium point. In the new equilibrium point, the increased input of organic matter will be counterbalanced by an increased decomposition of organic matter, so there will no longer be a CO_2-eq uptake from maintaining the same new plant cover. On the other hand, it will be necessary to maintain the supply of organic matter (plant cover) to prevent the carbon pool in the soil from returning to a lower equilibrium point, which will lead to CO_2-eq emissions.

Emissions from indirect nitrous oxide consist of atmospheric deposition and N leaching and runoff. The emissions are a derived effect of the supply of nitrogen to the field through fertiliser, crop residues, mineralisation, etc.

Table 7.8. Emissions from field operations

Sector	Emission source	Methane (CH_4)	Nitrous oxide (N_2O)	Carbon dioxide (CO_2)	Total (CO_2-eq)
			m tonnes of CO_2-eq in 2030		
The agricultural sector	Crop residues		0.9		0.9
	Atmospheric deposition		0.2		
	N leaching and runoff		0.4		
	Burning of biomass	0.0			0.0
	Mineralisation of the organic nitrogen pool		0.0		0.0
The LULUCF sector	Mineral soil on permanent agricultural land[1]			-0.3	-0.3
	Mineral soil on newly cultivated land			0.0	0.0
	Living biomass on permanent cultivated land			0.2	0.2
	Living biomass on newly cultivated land (deforestation)			-0.0	-0.0
	Dead wood as a result of deforestation			0.0	0.0
	Mineral soil on newly cultivated grazing land			-0.0	-0.0

Living biomass on permanent grazing land			0.1	0.1
Living biomass on newly cultivated grazing land			0.0	0.0
Dead organic matter on newly cultivated grazing land			0.0	0.0
Deforestation for agricultural land		0.0		0.0
Deforestation for grazing land		0.0		0.0
Total	**0.0**	**1.5**	**-0.0**	**1.5**

Note: The total does not add up due to rounding. 0.0 means that there are still emissions. It just doesn't show up to the 1st decimal place. "-" means that CO_2 is being absorbed.
1) Agricultural land refers to cultivated land and permanent grazing land.
Source: Climate Status and Outlook 2023 based on the emissions inventory.

Emissions and removals from forests etc. and other land use

Uptake and emissions from forests are measured from various sources, including the living biomass (i.e. the trees themselves and their roots), the forest floor and dead wood (branches etc.) and the soil itself. In addition to these, are storage in and emissions from harvested wood products. Removals and emissions from forests are accounted for in the LULUCF sector and calculated as changes in carbon pools between two periods. For example, if the total amount of dead wood increases between two periods as a result of increased growth in the forest, and this growth is greater than the ongoing decomposition of dead wood, a net uptake will be calculated.

According to the Danish Institute for Geosciences and Natural Resource Management, CO_2 uptake from forests and harvested wood products is estimated to decrease significantly until 2025, after which CO_2 uptake will increase slightly in 2030 and 2040. From 2025 to 2040, the annual CO_2 absorption in the forestry sector is thus estimated to be reduced by approx. 2.8 m tonnes of CO_2 relative to the CO_2 absorption in 2021, *see Table 7.9*, although the forest area is also estimated to increase towards 2030. The development is due to an expectation of increased thinning and felling in IGN's forest projection based on the current age structure of the forests. The average annual uptake in the period 1990-2020 was approx. 2 m tonnes of CO_2.

When trees are harvested, all the CO_2 that was previously sequestered in the trees is recorded as an emission. However, the part of the harvest where the carbon is instead sequestered in wood products will be transferred to a fund for Harvested Wood Products (HWP). Denmark's annual increment in the HWP pool is the part of the Danish harvest that is processed in Denmark into lumber, wood panels or paper. Every year, a portion of the sequestered carbon in the HWP pool is written off according to a writing-off period set in the IPCC guidelines. A write-off of uptake in HWP results in an emission.

Overall, the net increase in the Danish HWP pool in 2030 is estimated to be around 0.2 m tonnes of CO_2. In 2021, the uptake in the HWP pool amounted to approx. 22 per cent of the total registered logging in the same year, corresponding to a net uptake of approx. 0.1 m tonnes of CO_2, *see Table 7.9*.

Table 7.9 Emissions and removals from forests etc. and other land use

m tonnes of CO_2-eq per year	2021	2025	2030	2035
Emissions and removals from forests etc.				
Living biomass (underground and above ground)	-2.3	0.3	-0.2	-0.4
Forest floor (small branches, needles and leaves)	-0.7	0.1	0.1	0.1
Dead wood (dead trunks and thick branches)	-0.1	-0.3	-0.1	-0.1
Mineral soils	-0.1	-0.1	-0.1	-0.0
Carbon-rich soils	0.2	0.2	0.2	0.2
Forest in total	-2.9	0.3	-0.0	-0.2
Harvested wood products (HWP)	-0.1	-0.3	-0.2	-0.2
Forest and HWP in total	**-3.0**	**-0.0**	**-0.2**	**-0.3**
Emissions from other land use				
Buildings	0.2	0.3	0.3	0.3
Wetlands	0.1	0.1	0.3	0.3
Other land use	**0.3**	**0.4**	**0.6**	**0.6**

Note: The total does not add up due to rounding. 0.0 means that there are still emissions/uptake. It just doesn't show up at the 1st decimal place. Positive numbers represent net emissions; negative numbers are net uptake. HWP stands for "Harvested Wood Products".
Source: Climate Status and Outlook 2023.

Emissions in *the forest floor* category cover the fact that layers of small branches, needles, and leaves build up the carbon pool on the forest floor. The category of *dead wood*, on the other hand, covers carbon build-up based on larger trunks and branches that lie in the forest and decompose.

See *Denmark's National Inventory Report 2023*[44], mineral soil with forest is not a source of CO_2 emissions. As there is currently no separate emissions factor for forest floor soil for carbon-rich soils with 6-12 per cent carbon content, only forest floor soil with a carbon content above 12 per cent is included. Today, there are approx. 37,000 hectares of forest on carbon-rich soils (over 12 per cent), *see the forest inventory*. The estimated emissions from this area are 0.2 m tonnes of CO_2.

Emissions from other land use cover built-up areas and natural wetlands. Built-up areas are not associated with emissions per se but cover written-off emissions from before the area was built on.

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[44] DCE SR 541 https://dce2.au.dk/pub/SR541.pdf

7.4 IPCC Guidelines and Rules for the National Emissions Inventory

The guidelines from the Intergovernmental Panel on Climate Change (IPCC)[45] set the framework for Denmark's national emission inventory of greenhouse gas emissions and removals (negative emissions). Denmark's fulfilment of international obligations to the UN and the EU is tied to the annually reported emissions inventory to the EU and the UNFCCC, just as the emissions inventory is the basis for the Danish climate targets*, see the Danish Climate Act*.

The IPCC guidelines and the systematics of the emissions inventory are therefore important for the determination of relevant instruments and cost-effective achievement of international and national climate targets. The guidelines specify how a specific emission or removal can be included in the national emissions inventory to ensure the best possible degree of transparency, accuracy, comparability, consistency and completeness across country reporting. The guidelines are thus central to the estimated effect of a given regulation on emissions and removals (negative emissions) across sectors, including from the activities of the agricultural and forestry sector. At the same time, the guidelines specify documentation requirements for how emission-reducing climate measures can be included in national emission inventories.

International guidelines for the national emissions inventory

The national greenhouse gas inventory is reported annually in March to the EU and in April to the United Nations Framework Convention on Climate Change (UNFCCC). In Denmark, the DCE (the Danish Centre for Environment and Energy at Aarhus University) prepares yearly national greenhouse gas inventory based on activity reports from relevant authorities and research institutes.

The IPCC's international guidelines describe the framework for how emissions should be calculated and how emissions should be accounted for in predefined sectors across all countries.

According to the UNFCCC, all territorial emissions are categorised into five sectors:
1) The energy sector (including transport, households and industry),
2) The Industrial Processes and Product Use (IPPU) sector,
3) The agricultural sector,
4) The Land Use, Land-Use Change and Forestry (LULUCF) sector, and
5) The waste sector.

The IPCC guidelines are based on a territorial principle that emissions and removals are calculated in relation to the impacting activities they are associated with on the national territory. This means that the Danish emissions inventory must include emissions from activities that take place in Denmark, e.g. methane emissions from Danish cattle farming and emissions from fertiliser when it is applied. This means that each nation must account for emissions associated with activities within its own territory. At the same time, it ensures that emissions associated with, for example, the consumption of foreign products are included in the producing country's calculation. This ensures that all emissions are accounted for and avoids double counting.

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[45] IPCC (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Emissions from international shipping and aviation are handled under UN agreements with their own climate targets in the respective intergovernmental organisations for this purpose, respectively. IMO (shipping) and ICAO (aviation). Emissions from e.g. Danish ships in international waters are therefore not included in the Danish emissions inventory, but are subject to independent reduction targets.

The greenhouse gases covered are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and the so-called F-gases (e.g. refrigerants). The gases are included in the calculation based on the greenhouse effect of the gases converted to CO_2 equivalents (CO_2-eq) based on the Global Warming Potential (GWP) of each individual gas in a 100-year perspective in relation to CO_2, *see Box 1.1 in Section 1.2*.

As new knowledge emerges as a result of technological development, research, etc., IPCC guidelines and methods are continuously adjusted. This ensures that the national inventories reflect the latest knowledge and technology. Technologies that are covered by the IPCC's existing guidelines are included in the Danish national inventory when DCE has qualified that the effects of use are sufficiently documented. For all countries, the designated authority must qualify any adjustments according to specified guidelines from the IPCC. In practice, the reflection of detailed measures requires that emissions and removals are calculated with a detailed methodology that requires a high degree of national data, which therefore also requires a high degree of documentation.

The inclusion of the climate impact of new technology in national emission inventories is assessed through UN (and EU) review processes to determine whether there is sufficient evidence to support the inclusion. This ensures that all countries follow the same standards. If a technology is not covered by the IPCC guidelines, it will generally require the IPCC to update the guidelines before the effects of the technology can be recognised, or in some cases a national methodology can be developed that is qualified by the IPCC. Biochar produced by pyrolysis is an example of a technology where the IPCC guidelines do not provide a clear framework for recognising reductions from the technology, which is why national research is needed, *see Box 7.2*.

Box 7.2

Recognition of biochar in national inventory

Biochar produced by pyrolysis applied to land is included in the IPCC guidelines. However, the IPCC has currently only further defined the accounting principle for biochar in agricultural land and grazing land in the LULUCF sector. This means that the climate effect of storing carbon in the form of spreading biochar on agricultural land can be included as negative emissions (removals) in the Danish national emissions inventory when the DCE has approved a method for calculating the effects of biochar added to agricultural land. The preparatory work for the development of the methodology has been initiated.

According to the DCE, the application of biochar on other soil types such as paved areas, forests, etc. is in principle covered by the IPCC guidelines. The IPCC specifically states that the method for calculating biochar stored in agricultural land and grazing lands does not apply to forest areas, wetlands and sealed areas. Since the guidelines do not explicitly address forest areas, wetlands and paved areas, it is even more up to the countries themselves to develop a methodology. The methodology will have to go through an extensive UN review process before the climate impact of these forms of storage can be recognised in the national inventory. Such work has not been initiated.

It also follows from the IPCC guidelines that reductions from CO_2 capture can only be included in the calculation when there is subsequent permanent storage. For capture without permanent storage, emissions must be included in the emission inventory. The IPCC does not define what permanent storage is, but refers to geological storage.

The guidelines do not describe the storage of biochar in above-ground storage with an aim for permanent storage. This means that the framework and circumstances that must be met before the storage can be labelled as permanent storage and thus be recognised as a reduction in the calculation are not specified. Clarifying this is estimated to be an even more extensive UN review process, including the development of principles, methodologies and possibly standard factors.

Alternative uses of biochar, e.g. in building materials, are not covered by the IPCC guidelines. It will, therefore, require a revision of the guidelines before the effects of this type of use can be recognised in national emissions inventories.

The guidelines were last adjusted in 2019. Since the Paris Agreement, a note has been added to the COP26 reporting format to ensure that some forms of CCS associated with industries or power plants that are fuelled wholly or partly by biomass (Bioenergy with Carbon Capture and Storage (BECCS)) can be included. Technological developments towards 2030 could potentially increase the pressure for an update of the IPCC guidelines. In January 2024, the UN Member States agreed, among other things, that the IPCC should prepare a methodology report on emissions inventories for "Carbon Dioxide Removal Technologies, Carbon Capture Utilization and Storage", to be completed in 2027. The detailed content of the methodology report, including whether pyrolysis and biochar will be part of the report, is expected to be finalised in 2024. After the finalisation of the methodology report in 2027, it must be decided whether the IPCC guidelines should be revised on this basis. Experience has shown that revising the guidelines is a relatively extensive process that can take up to several years. In addition, all new IPCC guidelines must subsequently be adopted under the UN Framework Convention on Climate Change, either as mandatory or voluntary for countries.

Adjustments in calculation methods or adjusted emissions factors for individual emission sources will both change CO_2 emissions, but also affect CO_2 emissions backwards and forwards to ensure time series consistency. This means that the entire reported time series will be recalculated, and in some cases adjustments may be made all the way back to 1990.

Calculation of emissions in the national emissions inventory

Emissions and removals from the agriculture and forestry sector are generally associated with the agriculture and LULUCF sectors, *see IPCC's categorisation*. Energy-related emissions from agriculture, e.g. diesel consumption, are calculated in the energy sector, which was covered in the first interim report.

Emissions from the agricultural and LULUCF sectors are measured differently. Emissions from the agricultural sector are calculated based on the biological processes from agricultural activities in agricultural production: primarily methane and nitrous oxide emissions from livestock digestion and fertiliser management, as well as nitrous oxide emissions from fertiliser applied to fields. Emissions and removals in the LULUCF sector are calculated based on changes in carbon pools from the entire area of Denmark, which is categorised into agricultural land, grazing land, forest and buildings.

The starting point for *Climate Status and Outlook* is that climate effects are not recognised until a national calculation method or emissions factor has been developed and approved by the DCE.

The regulation of emissions from the agricultural and forestry sector must, as a starting point, be based on the systematisation and categorisation in DCE's inventories, so that the regulation supports reductions in accordance with the national emissions inventory. It can be politically decided that this practice should be changed in relation to Danish objectives.

The governmental platform behind the Expert Group's models follows the systematics and categorisation in DCE's inventories. A regulation that deviates from the systematics and IPCC categorisation in the national emissions inventory can, in the worst case, create inappropriate incentives that lead to more emissions, just as it can lead to a risk of double counting across sectors, *see Box 7.3*.

Box 7.3

Biogas based on livestock manure in the Danish emissions inventory

According to IPCC guidelines, territorial greenhouse gas emissions of methane (CH_4), nitrous oxide (N_2O) and CO_2 are accounted for in the agricultural sector as well as the other sectors. CO_2 from biogenic sources such as biomass is recognised in the LULUCF sector in the country of origin of the biomass. CO_2 from biogenic sources is therefore recognised as CO_2-neutral in the energy sector, among others.

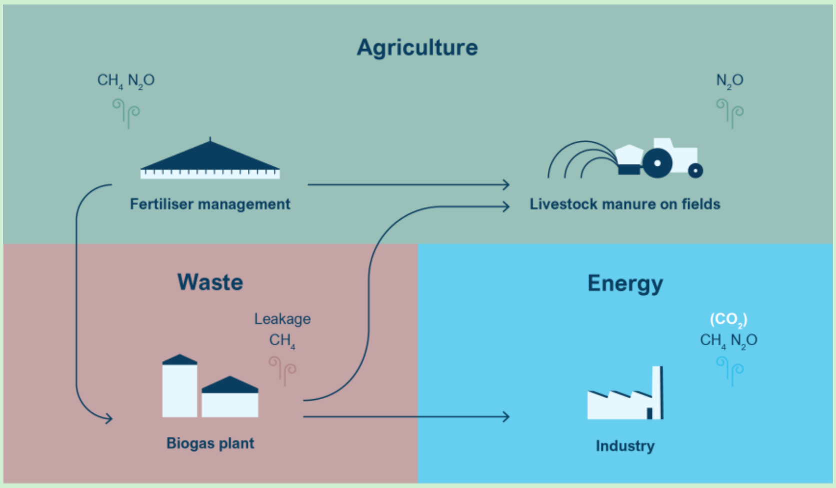
Livestock manure causes methane and nitrous oxide emissions in the agricultural sector. Emissions are calculated in connection with fertiliser management in stables and storage facilities, as well as nitrous oxide emissions from manure spread on fields.

Fertiliser management can produce methane from the carbon content of livestock manure when the fertiliser is in low-oxygen conditions in stables and storage facilities. The emissions are included in the agricultural sector and can be reduced by different types of housing and measures, including frequent removal, see Technology Catalogue.

If livestock manure is to be used for biogas production, it means that the manure must be quickly transported from the stable to the biogas plant. This will reduce methane and nitrous oxide emissions in fertiliser management, as the livestock manure stays for a shorter time in stables and storage facilities and, therefore, does not produce the same amount of methane. Specifically, the reduction will result from, e.g. frequent removal and will be recognised in the agricultural sector.

When methane is burned in the energy sector, the methane is converted to CO_2, and since the $CO_2$is formed from a biogenic source, it is calculated as CO_2-neutral in the energy sector, *see IPCC guidelines*. Therefore, the use of biogas in the energy sector can lead to reductions if the biogas replaces fossil fuels. There will be very limited methane and nitrous oxide emissions associated with the burning of biogas, which are recognised in the energy sector. In addition, biogas production can be associated with methane leakage from the biogas plants due to leaks etc. These emissions are recognised in the waste sector.

Livestock manure will typically be spread on agricultural land. The application of livestock manure will be associated with nitrous oxide emissions. This applies to both livestock manure that is not used as input for biogas production and livestock manure that is degassed at biogas plants. Nitrous oxide emissions are unaffected by whether or not the manure is degassed in connection with biogas production and are recognised in the agricultural sector. There may also be derived benefits for the farmer, as degassing livestock manure can increase the quality of fertiliser, thereby reducing the need for and use of fertiliser.



Calculation methods for the national emissions inventory

The IPCC guidelines contain detailed calculation formulas for calculating emissions, as well as descriptions of the data that should be collected for this purpose. Again, this ensures that there is a consistent standard across countries. For the majority of the emission sources in the national emissions inventory, the IPCC guidelines specify three possible tier levels that can be used to calculate emissions, *see Box 7.4*.

Box 7.4

IPCC classification of tier-level calculation methods

Tier 1
A Tier 1 method is the simplest calculation method using the IPCC standard emissions factors. The IPCC also provides suggestions on where to find activity data for a given source. Emissions are calculated by multiplying activity data (AD) by an emissions factor (EF) in the simple formula: Emissions = AD × EF

Tier 2
A Tier 2 method requires more country-specific data rather than the IPCC's standard emissions factor. There is variation across emission sources as to what specifically constitutes a Tier 2 method, but the method follows the same formula as for tier 1. There are also requirements for scientific documentation of why the country-specific factor is considered more accurate than the IPCC's standard emissions factor. While the overall calculation method is simple in itself, the specific calculations can be relatively complex, for example by including broad data from many samples. In particular, the need for more detailed activity data to be collected annually complicates the use of Tier 2 and 3.

Tier 3
A Tier 3 method is a calculation method that is developed on a country-specific basis. It differs in that it is based on measurements and/or modelling and therefore does not follow the simple formula of Tier 1 and Tier 2. Tier 3 methods should be documented by scientific publications and detailed methodology reports and, according to the IPCC, should be peer-reviewed and undergo quality assurance. The purpose of the quality assurance is to avoid any bias in the emission estimate.

There are no specific requirements in the guidelines as to which tier levels should be used to calculate emissions from individual emission sources. This means that countries are free to choose whether to use the IPCC's standard emissions factors or more detailed national emissions factors to calculate specific emissions. It is generally recommended that emission sources identified as "key categories" use a minimum of Tier 2. Key categories include emissions related to fertilisers applied to fields, livestock and cultivation of carbon-rich agricultural land. These emission sources have a significant impact on the country's emissions either quantitatively or show a significant trend over the years.

In the Danish emissions inventory, different methods and types of emissions factors are used to calculate emissions in the agricultural and forestry sector. For Tier 1 and 2 methods, emissions are typically calculated based on recorded or estimated activities, such as the number of cows or the amount of fertiliser applied. For these areas, there will be a simple correlation between e.g. regulatory base and inventory. For other types of calculation methods, several variables may be included in the calculation of emissions from an activity, e.g. rainwater volume and cultivation history, which is why there will not immediately be a simple connection between the regulatory basis (the activity that the farmer can influence) and the calculation of emissions.

In general, the emissions inventory is subject to uncertainty, including in relation to the estimation of activity data and emissions factors. Uncertainties in the agriculture and LULUCF sectors are generally higher than in other sectors. However, this is especially true for those emissions in LULUCF that are biologically determined, where temperatures, humidity, chemistry, nutrient availability and microbial activities, among other things, determine the final emissions.

Inclusion of new measures in the national emissions inventory

Including new measures in the national emissions inventory requires documentation of the reduction effect and activity data (deployment and operating conditions).

In this context, it is recommended that the relevant authorities work together to prioritise the provision of research results and documentation in order to ensure that new technologies are incorporated into the DCE's inventories as soon as possible.

Technologies and transition elements for reducing agricultural emissions are at different stages of maturity, *see Appendix 7.5*.

When introducing voluntary subsidy schemes or reduced taxes in connection with the use of technologies or transition elements, it is necessary to ensure the compilation of activity data. If a measure is stipulated by law, the emissions inventories can assume that the law is followed and the measure is therefore widespread.

For example, if the use of methane-reducing feed is to be calculated in the national emissions inventory, two types of data must be obtained before the DCE can approve the technology. Firstly, representative impact data must be collected. Efficacy data documents that methane-reducing feed has the claimed reduction effect when national differences in feed composition and ration are taken into account. Secondly, activity data must be collected, which is data on actual usage in Denmark. The two types of data must ensure that there is certainty about both the effect of the individual technology and the extent to which the technology is used in practice. For example, for the methane-reducing feed additive Bovaer, it is estimated that with the research activities initiated, there will be sufficiently solid results for the technology to be included in the national emissions inventory. It is possible to include estimates for the uptake of the technology in the projection.

7.5 Technology Catalogue

This chapter provides an overview of the current options for technical transition in the agriculture and LULUCF sector.

The options for technical transition in the agricultural sector relate to livestock digestion, manure management and fertiliser application, and for the LULUCF sector, soil carbon uptake. The options for technical transition are generally limited in their impact, have high socio-economic costs (low cost-effectiveness), and are low in maturity.

Most of the option for technical transition presented in this chapter correspond to what is presented in the government's *Climate Programme 2023* from September 2023.

Overview of technologies

Table 7.10 provides an overview of the currently known technological transition elements for agriculture and LULUCF. Estimates have been made for potential, costs, side effects, maturity level and the status of being able to recognise the effects of technical conversion options in the emissions inventory.

The effects in the technology catalogue deviate from several stakeholders' assessment of the potential for technological change in agriculture. This is largely due to the fact that the effects in the table below can be recognised in the *Climate Status and Outlook*, which ensures that there is no overlap between effects recognised as a result of previous political agreements, e.g. the Agricultural Agreement and various financial laws.

Many of the transition elements are substitutes and their effects cannot be added together within the same emission source. *Table 7.10* shows the full potential for each technology. For a number of technologies, overlaps will need to be taken into account, which is why the potentials cannot be summarised. In the calculations of the presented models, overlaps and substitutes are taken into account.

The technical reduction potential examines solely the technically possible reduction, based on the limiting factors such as area or number of animals. It does not take into account the possibilities for realising the transition elements, e.g. whether it is possible to install tent covering with floating layers on all slurry tanks or to build a certain number of pyrolysis plants by 2030.

The assessment of the total potential in 2030 is based on a summation of the median estimates for each of the instruments. Realisation in 2030 will depend on when and how the instruments are incentivised, as there may be practical challenges associated with rolling out all the instruments over a short number of years towards 2030.

The current maturity level of the technologies from a purely technical point of view is indicated by a Technology Readiness Level (TRL) scale 1-11 (1= low maturity, 11= high maturity), which is based on the International Energy Agency's Clean Energy Technology Guide 2021. The maturity of the technologies is continuously monitored. There is a big difference in maturity. For the feed additive Bovaer, for example, there is reasonable certainty of efficacy, but efficacy documentation under Danish conditions is pending. For the storage technology tent covering with floating layers, documentation for efficacy is pending, while nitrification inhibitors are being studied for both efficacy under Danish conditions and possible environmental impact (groundwater pollution).

It is generally required that the reduction effect of a given technology is well documented and included in the IPCC guidelines in order to include it in the emissions inventory. *Table 7.10* indicates the following for each technology: ready, if it can be immediately recognised today, possible, if research projects have been initiated that are expected to document the effect before 2030, uncertain, if research projects have yet to be initiated to document the effect or side effects, and difficult, if the technology is considered so immature that it is unlikely to be realised before 2030. The categories only cover documentation of the reduction effect. This does not take into account activity data and penetration, which are also necessary data to recognise the effect in the emissions inventory.

It should be noted that these are uncertain estimates of costs and reduction potentials. There is a general uncertainty associated with estimating future technological development. Description of the individual technologies follows *Table 7.10*.

Table 7.10. Current known technical transition options for agriculture and LULUCF

Technology / Transitions element	Technological costs in factor prices (DKK per tonne)	Positive side effects in factor prices (DKK per tonne)	Reduction potentials (m tonnes in 2030)1)	Limiting factor	TRL 1-11 (maturity)	Status for inclusion in the emissions inventory in 2030
Agriculture, Livestock digestion (effects from the different feed measures cannot be added together)2)						
Bovaer (feed additive)	425	0	0.50	Number of conventional dairy cattle. Organic cattle cannot receive Bovaer. Bovaer cannot currently be used when cows are grazing.	9	Possible
Substance X2 (feed additive)	-	0	0.7	Number of conventional cattle and whether it will be EU-approved for all conventional cattle.	2	Uncertain
Nitrate	.	Negative	0.13	Number of conventional dairy cattle and safe allocation method.	6	Uncertain
Tropical red algae	.	.	1.3	Animal health – the seaweed is being risk assessed. Whether the seaweed is organic.	1-4	Uncertain
Fertiliser management in stables						
Stable acidification, cattle (excludes other measures including storage facilities)	1,000	200	0.04	Number of conventional dairy cattle. Slurry cannot be used for biogas. Can only be used in some types of housing	9	Possible
Slurry cooling, new stables	4,825	150	0.02	The number of newly constructed barns from 2025.	9	Ready

Slurry cooling, existing stables			0.05	The calculation does not differentiate between new and old stables.	9	Ready
Change of type of housing – pigs [3)]	-	0	0.07	Potential is limited by new requirement for frequent removal.	9	Possible
Slurry removal every 7 days	-	-	-	Relevant in pig barns, as new cattle barns are established with daily removal or stable acidification due to current environmental regulations.	9	Possible
Slurry and fertiliser management in storage						
Tent covering + floating layer – pigs	300	0	0.12	Not relevant if slurry is acidified or set aside for biogas.	7	Uncertain
Tent covering + floating layer – cattle	425	0	0.04	Not relevant if slurry is acidified or set aside for biogas.	7	Uncertain
Storage acidification - pigs	.	.	0.08	Same as tent covering	6	Possible
Storage acidification – cattle	.	.	0.04	Same as tent covering	6	Possible
Flaring – pigs	.	.	0.15	Same as tent covering	6	Possible
Flaring – cattle	.	.	0.07	Same as tent covering	6	Possible
Biofilter – pigs	.	.	0.18	Same as tent covering	6	Possible
Biofilter – cattle	.	.	0.08	Same as tent covering	6	Possible
STAF/Nogas	.	.	-	.	3	Difficult
Washing robots	.	.	.	.	3	Difficult
Nitrogen application on fields						
Nitrification inhibitors – added to livestock manure[4)]	1,250	Positive	0.17	Total amount of livestock manure. Risk of groundwater contamination is investigated.	9	Uncertain
Nitrification inhibitors – added to inorganic fertiliser[4)]	1,500	Positive	0.22	Total amount of inorganic fertiliser. Risk of groundwater contamination is investigated	9	Uncertain
LULUCF						
Carbon balance in cultivated soil [5] (effects from the different cultivation methods cannot be added together)						
Catch crops[5)]	-	Positive	-	Agricultural land	9	Ready
Catch crops[5)]	-	Positive	-	Agricultural land	9	Ready
Winter crops (early sowing)[5)]	-	Positive	-	Agricultural land	9	Ready
Fallowing[5)]	-	Positive	-	Agricultural land	9	Ready
Perennial energy crops[5)]	-	Positive	-	Agricultural land	9	Ready
Grass in crop rotation[5)]	-	Positive	-	Agricultural land	9	Ready
Biochar by pyrolysis[6)]	900-3,300	-	0.8-38	Agricultural land Environmental authorisation of quantity per hectare (phosphorus cap)	9	Possible

Note: Technological costs are stated in 2023 factor prices, administration costs etc. are not included. For capital investment, a required rate of return of 7 per cent is assumed. Costs and side effects are rounded to the nearest DKK 25 per tonne. TRL *technology readiness level* (1= low maturity, 11= high maturity). 1) The reduction potentials are calculated additionally in relation to KF23. 2) The general requirement for livestock digestion from the Agricultural Agreement corresponding to increased fat feeding has been deducted from the technologies' potentials, as there is currently assessed to be full overlap. It is uncertain whether this is possible for organic cattle. 3) It is a prerequisite for the use of nitrification inhibitors that negative side effects are clarified, including the risk of groundwater contamination via leaching to groundwater. 4) It has not been possible to estimate the cost curve and climate effect for the individual field management measures. 6) The technical potential for biochar reflects a range if biochar is produced only on digestate, which has the highest phosphorus content (the 0.8 m tonnes of CO$_2$-eq), and if biochar is produced only on wood, which has the lowest phosphorus content (the 38 m tonnes of CO$_2$-eq).

Agricultural sector

Livestock - digestion

Methane is formed in the rumen during the digestion of feed in ruminant livestock, but various measures can reduce methane emissions from livestock digestion and thus reduce the emissions factor per animal. Cattle have by far the largest methane emissions from digestion, which is why methane-reducing technologies target cattle.

It is not fully clarified whether the different types of methane-reducing feed have an additional effect when used together or whether their effects are mutually exclusive. Studies already conducted have not demonstrated additive effects when using several types of methane-reducing feed at the same time, which is why the possibilities are considered to be limited. However, it should be noted that different types of methane-reducing feed can be used simultaneously for different types of cattle. An example is the feed additive Bovaer, which is only authorised for conventional dairy and breeding cows, and the feed additive Substance X2, which is expected to be used for beef cattle as well. Therefore, the expected future distribution of conventional and organic dairy cattle will affect the potentials, just as the potentials will depend on the number of cattle in 2030.

It was decided with the Agricultural Agreement to implement a general reduction requirement for conventional cattle digestion from 2025, corresponding to an effect of approx. 0.2 m tonnes of $_2$-eq in 2030 based on an increased proportion of fat in the feed, but with methodological freedom. However, increased fat content is not expected to be utilised with the other feed additives.

For a number of the methane-reducing measures, sufficient documentation of the climate effect and studies of side effects on animal health and the environment are still lacking.

Bovaer/3-NOP (feed additive)

Bovaer (with the active ingredient having the chemical name 3-NOP) is a feed additive approved in 2022 as the first methane-reducing feed additive in the EU, and is expected to be marketed in Denmark within a shorter timeframe. It is expected that the substance will be marketed in complementary feed that is mixed into the feed. Bovaer is authorised for use in conventional dairy cows and breeding cows, while it is currently not authorised for use in organic cattle[46]. The substance is sold today in e.g. Netherlands, Belgium, Italy and Australia.

The climate impact of using Bovaer under Danish conditions is the subject of an ongoing research project with the final report being due in 2024. Among other things,

[46] Bovaer is currently not authorised for organic cattle because it is synthetically produced.

the research project aims to clarify whether the effect of Bovaer can be included in the national emissions inventory for 2025.

The effect of Bovaer depends on the feed ration to which it is added. In a Danish feed ration, the substance is expected to reduce methane emissions by up to 30 per cent, which corresponds to an additional reduction of approx. 0.5 m tonnes of CO_2-eq in 2030. The reduction effect is adjusted for the general reduction requirement. Bovaer need to be fed daily in the barn, but feeding methods for grazing cattle are currently being worked on, which is expected to be possible in two years. It is also expected that Bovaer will have a similar effect on heifers as it does on dairy cows. SEGES has estimated that this reduction will amount to around 0.17 m tonnes of CO_2-eq. However, the climate impact on heifers still needs further documentation before it can be included in the national inventory.

COWI has estimated the cost of purchasing Bovaer based on dialogue with the manufacturer and on the basis of the price of a specific product. On this basis, it is estimated to cost the industry in the region of DKK 250 m annually to feed all conventional dairy cattle with Bovaer. The technological costs are estimated to be around DKK 425 per tonne of CO_2-eq.

Substance X2 (feed additive)
At Aarhus University (AU), research is being conducted into the development of a methane-reducing feed additive called 'Substance X2', which is expected to be used for conventional cattle. As the substance is still being patented, the content of Substance X2 is not publicly known, nor has a timeline been set for the publication of the research results

According to AU, Substance X2 is expected to reduce methane emissions by up to 30 per cent for all conventional cattle, which corresponds to a reduction potential of approx. 0.7 m tonnes of CO_2-eq. Substance X2 could potentially reduce methane emissions by up to 40 per cent if a so-called "triple-action" product is successfully developed with Substance X2 as a sub-component. In this case, the potential would be up to 1 m tonnes of CO_2-eq in 2030. However, there is considerable uncertainty about whether this can be realised in practice.

Substance X2 is currently not market-ready, and it is not used anywhere in the world as it is still under development. This includes further clarification of how Substance X2 affects animal health, including whether it has any derived effects on feed intake and milk yield.

Nitrate
Calcium nitrate (nitrate for short) is a feed additive that works by removing some of the hydrogen produced in the cow's rumen that would otherwise be used to create methane. Therefore, changing the composition of the feed ration through increased addition of nitrate could potentially reduce methane emissions from livestock digestion. Nitrate can potentially be used for all types of cattle in conventional farming, but not by organic farmers.

Research indicates a 10 per cent reduction in methane emissions from cattle digestion. The limiting factor for the use of nitrate is considered to be the high content of nitrogen in nitrate, which means that nitrate must replace other nitrogen-containing feed materials in the ration to avoid a reduction in methane emissions being fully or partially offset by an increase in nitrogen emissions. Further clarification of both the environmental effects and how nitrate affects animal health is also needed.

Seaweed, algae, etc. in feed
Seaweed in feed is an example of a feed additive that is currently very immature and where the health and other side effects have not yet been analysed. Other feed additive measures include essential oils, plant extracts, etc.

Initial studies have indicated that seaweed added to feed can have a reducing effect on over 50 per cent of methane emissions from digestion in young cattle, but only 25-35 per cent in dairy cattle. The estimate is uncertain and research is ongoing. The European Commission has asked the European Food Safety Authority (EFSA) to assess the risks of using red algae in feed, but they do not expect to present a risk assessment until 2024 at the earliest.

Livestock - Fertiliser management in stables
Storing slurry in the barn before transferring it to storage releases methane and nitrous oxide as it evaporates. Different stable systems have different surface areas and capacity for slurry. Changing these factors can change the emissions factor per animal. In addition, technologies can be added to treat the slurry while it is stored.

Switching to a stable with more frequent slurry discharge and installing stable acidification are mutually exclusive. This is because it is not relevant to establish barn acidification in barns that are already climate-friendly due to their slurry handling system with wire-type stable cleaners/scraper. Slurry cooling can be established at the same time as stable acidification and a change in the type of housing. In practice, however, it is often a choice between a stable acidification system or a slurry cooling system, as there are high costs associated with both.

Change in type of housing - pigs
A farm's choice of stable is closely linked to animal type with a particular determinant being the market situation (demand, price formation, production costs, etc.), where the entire production apparatus (stable, storage, technologies, etc.) is geared towards a specific type of animal. However, it is possible to change the stable for a given animal type, which would be a purely technical conversion. Choosing a "low emission stable" will reduce the emissions factor per animal.

The total reduction potential for pig farms is estimated to be less than 0.07 million tonnes of CO_2-eq in 2030. The cost range of -100 - 84,000 covers different production types, herd sizes and whether the existing stable system has been depreciated. The majority of the potential effect is associated with a high shadow price. The range of the shadow price is large, as it depends on the specific type and age of the stable. For all types of production, the technological costs exceed DKK 8,000 per tonne of CO_2-eq if the type of housing is changed before the existing housing is depreciated. If only fully depreciated barns are included, the potential is less than 0.01 million tonnes in 2030.

When changing the stable system, the reduction effect depends on the slurry's residence time in the stable. The potential is limited by the fact that there is a general requirement for frequent removal from pig houses as a result of the Agricultural Agreement that came into force on 1 May 2023. The distribution of stable systems across animal types with their respective emissions factors are included in the emissions inventory based on the fertiliser register.

Stable acidification, cattle

During acidification in stables, the pH value in the slurry is lowered by the allocation of sulfuric acid via a stable acidification plant, reducing the turnover and formation of methane and ammonia in the slurry. Stable acidification has the advantage that the reduction effects in the stable are expected to be retained in the storage facility. Livestock acidification is a mature technology due to its use as an ammonia-reducing technology. However, the climate impact still needs further documentation before it can be included in the national inventory. With stable acidification, the use of the slurry for biogas is excluded, as sulphuric acid is incompatible with biogasification.

Based on estimates for the spread of the technology, which are based on the spread of types of housing where livestock housing acidification can be directly implemented, it is estimated that the technological costs associated with an increased share of stable acidification amount to DKK 575-3,950 per tonne of reduced CO_2. There is an estimated potential to reduce emissions by 0.04 million tonnes of CO_2-eq in 2030. The starting point for this potential is that only existing and new cattle stables with a ring channel that does not already acidify the stable or supply biogas can be converted. Further documentation of possible negative side effects on the environment is still pending. In addition, it is estimated that there is an additional potential of 0.42 million tonnes of CO_2-eq in 2030, for which technological costs cannot be estimated. Realising this potential will require remodelling the type of pig housing that do not have slurry channels. Overall, the shadow price of converting pig houses is estimated to be significantly higher than the estimates given here.

Slurry cooling, without the possibility of utilising excess heat

Slurry cooling lowers the temperature of the slurry while it is stored in the stable, thereby reducing the conversion and formation of methane. Slurry cooling is only relevant in pig houses, which are typically closed stable systems. Slurry cooling is a mature technology due to its use as an ammonia-reducing technology. Slurry cooling does not technically exclude any other slurry and fertiliser technologies. Slurry cooling contributes to both ammonia and methane reduction. By using slurry cooling, the excess heat can be utilised. It is estimated that further use of slurry cooling will take place in stables where the excess heat cannot necessarily be utilised.

The technological costs associated with an increased share of slurry cooling systems amount to DKK 4,250-6,125 per tonne of CO_2-eq reduced. Based on the technological costs, it is estimated that there is a potential to reduce emissions by 0.02 million tonnes of CO_2-eq. The potential is limited by the assumption that slurry cooling is not implemented in existing stables, as this would require extensive and costly remodelling. Therefore, it is estimated that there is an additional potential of 0.05 million tonnes of CO_2-eq in 2030 for which technological costs cannot be assessed (existing stables).

Final documentation for slurry cooling has yet to be finalised, including the optimal operation of a plant to reduce methane from the slurry.

Livestock - Fertiliser management in storage

There is full overlap between the different technologies for handling slurry in the storage facility. At the same time, the storage technologies will have no effect in combination with stable acidification. Conversely, the best effect will be achieved if storage technologies such as low-dose storage acidification are combined with frequent removal from the stable or slurry cooling at the stable.

Tent covering with floating layers

Tent covering on the slurry container combined with a natural floating layer on top of the slurry reduces greenhouse gas emissions by stabilising the water balance of the floating layer, and makes it possible to regulate the air exchange with the aim of maintaining an elevated concentration of methane in the air above the floating layer. Although tent coverings and floating layers are used individually as ammonia technology, the combined technology as a climate technology is very immature due to the concept being in the pilot phase. Tent covering with floating layers are not relevant for slurry sent to biogas, as the slurry is not stored in the slurry tank before degassing. It is estimated that the technological costs associated with an increased proportion of tent roofing with floating layers amount to DKK 75-975 and DKK 50-875 per tonne of reduced CO_2-eq for pig and cattle slurry, respectively. The range in costs covers different costs depending on the size of the slurry tank. Especially slurry tanks where a tent covering is already installed will have low costs, as only the floating layer needs to be installed. Based on the technological costs, it is estimated that there is a potential to reduce emissions by 0.16 million tonnes of CO_2-eq. Final documentation of the reduction effect on greenhouse gases and more detailed knowledge of construction and operation are still pending.

Low-dose storage facility acidification
Low-dose acidification in the slurry tank lowers the pH of the slurry by adding sulphuric acid to the slurry tank while stirring the slurry. The combination of added sulphur from sulphuric acid and a lowered pH means that the formation of methane is inhibited. Storage facility acidification is currently used as an ammonia-reducing technology, but is added just before application and therefore only has an effect out on the field. Low-dose acidification in storage facilities is an immature technology. Further research is needed on, for example, acid dose and optimal addition and mixing methods before the concept is ready for implementation as a methane-reducing technology. Low-dose storage facility acidification is not relevant in combination with biogas, as slurry is typically delivered to biogas plants directly from the stable. Low-dose storage facility acidification could potentially fulfil two requirements at once, ammonia and methane reduction. The total technical reduction potential is estimated to be 0.12 million tonnes of CO_2-eq in 2030. Documentation of the reduction effect and more detailed knowledge about the operation of the technology is pending.

Flaring
In flaring, the methane emitted from the slurry is collected in the air above the slurry tank under a tightly sealed tent, then discharged into a flare and burned. Flaring is not considered relevant in combination with stable acidification or with biogas, as slurry is typically delivered to biogas plants directly from the stable and as acidification is assumed to reduce or eliminate methane emissions from the storage facility. Flaring is a known technology for burning methane in landfills (e.g. Danish company Deponigas). However, flaring in slurry tanks is still early in the research and development phase, and the final concept is not yet known. At this point, only a prototype for slurry storage has been developed. The technical reduction potential is 0.23 million tonnes of CO_2-eq in 2030. There are uncertainties associated with the potential, including a lack of documentation of the reduction effect on greenhouse gases, design and operation.

Biofilter
Biofilters work by collecting the methane-containing air from slurry stores and blowing it into a layer of soil or compost, where methane-oxidising bacteria break down methane into CO_2. The same principle is currently used in landfills under the term bi-

ocover, but the technology's effect has not yet been proven in slurry storage facilities. Biofilter is an immature technology due to the lack of documentation of the reduction effect and the lack of repeated full-scale testing. Biofilter is not considered relevant in combination with stable acidification and is not relevant in combination with biogas, since slurry is typically delivered to biogas plants directly from the stable and since biofilter is assumed to reduce or eliminate methane emissions from the storage. Overall, biofilter is estimated to have a technical reduction potential of 0.26 million tonnes of CO_2-eq in 2030. The assessment is subject to a number of uncertainties, partly due to the still incomplete documentation of the reduction effect.

STAF/Nogas

STAF is a slurry additive whose active ingredients tannin and fluoride reduce microbial activity in the slurry, preventing the formation of methane and ammonia. In laboratory trials, STAF has shown a promising reduction effect on methane and ammonia in the slurry before application, as well as a reducing effect on nitrous oxide emissions during application. In 2019, the University of Southern Denmark's project managers have roughly estimated that if STAF is used on 50 per cent of all slurry in Denmark, the additive will potentially reduce greenhouse gas emissions from agriculture by 0.4-1 million tonnes of CO_2-eq annually. The assessment has been made without consideration of the overlap between this technology and other technologies (such as biogas). This potential is associated with significant uncertainties, as the technology has not yet been fully developed or tested in practice in stables and storage facilities. The documentation behind the estimated potential is based on laboratory tests and is therefore still very incomplete, as field trials under Danish conditions are still pending.

Washing robots

A washing robot is a robot that can wash the slurry pits in pig houses. With a washing arm, the robot removes all residual fertiliser and bacteria from the slurry channels between each batch of pigs, thus providing poorer growth conditions for the methane-producing bacteria. An ongoing GUDP project, GreenSlurry, expects that the washing robot can reduce total methane emissions from stables and storage facilities by up to 60 per cent. However, this estimate is associated with significant uncertainties due to the low maturity, which is why it is not considered possible to estimate a technical reduction potential for the technology.

Field application of nitrogen - Decomposition of nitrogen in the field

Nitrogen applied to fields can be converted into nitrous oxide when it comes into contact with soil microbiological life. By 2030, changes are expected in the way nitrous oxide emissions from agricultural fertiliser usage are measured, as current assumptions do not match actual measurements in the field. Current research indicates that the emissions factor for fertilisers is lower than the emissions factor from livestock manure.

Nitrification inhibitors

Nitrification inhibitors have been developed as a means to optimise the utilisation of fertilisers and manure applied to fields. The addition of nitrification inhibitors reduces nitrous oxide emissions from the applied fertiliser and manure, thereby reducing the emissions factor per unit of manure/fertiliser applied.

It is estimated that the technological costs associated with the use of nitrification inhibitors amount to DKK 1,325 and DKK 1,225 per tonne of reduced CO_2-eq for livestock manure and non-organic fertiliser, respectively. The potential to reduce emissions is estimated at 0.39 million tonnes of CO_2-eq overall. The addition of nitrification inhibitors to fertilisers is estimated to have a positive side effect in the form of reduced nitrogen leaching to the aquatic environment.

Research is ongoing into the climate impact of nitrification inhibitors under Danish conditions and whether they pose a risk of contaminating drinking water. It is a prerequisite for the use of nitrification inhibitors that negative side effects are clarified, including the risk of leaching to groundwater. If the preliminary results from ongoing Danish research into the emissions of nitrous oxide in relation to fertiliser application show that the emissions factor for non-organic fertilisers is lower than previously assumed, this will mean that the use of nitrification inhibitors in non-organic fertilisers has a significantly smaller reduction effect. The research projects are expected to report in 2024.

LULUCF sector

Carbon balance in cultivated land - Change in carbon pools

Changes in the soil's carbon pool are calculated in a dynamic model with historical input data. The key is that the carbon pool is moving towards *equilibrium*. If the same amount of biomass is added to the soil annually, the same equilibrium is maintained, keeping the soil carbon pool constant. If the amount of biomass added increases, other things being equal, there will be an increased carbon uptake until a new equilibrium with a larger carbon pool is reached, and if the amount of biomass added decreases, other things being equal, there will be an increased emission until the adaptation to a new equilibrium with a lower carbon pool. The carbon balance is sensitive to weather changes, so a new temperature projection will affect the calculations.

The different types of biomass can replace each other to a certain extent, so for example, biomass from straw can be replaced by several cover crops, although not necessarily 1:1.

Catch crops

Catch crops are grown after harvesting the main crop and take up excess nitrogen in the soil, reducing leaching and ideally making the nitrogen available for next season's crop production. In terms of climate impact, the cultivation of catch crops will lead to a reduction in indirect nitrous oxide emissions. This is due to reduced leaching and runoff of nitrogen, reduced nitrous oxide as a result of reduced fertiliser usage and increased carbon uptake in the soil through the greater amount of plant residues in the field. Note that the carbon build-up in the soil follows a decreasing curve until the saturation point is reached. At the same time, the effect is reversible. Decomposition of plant residues from catch crops leads to increased nitrous oxide emissions and a marginal increase in ammonia emissions.

Nitrogen regulation includes the following schemes to limit nitrate leaching from the root zone: 'Targeted regulation', 'mandatory catch crops' and 'livestock catch crops'. In all schemes, the farmer can choose between several alternatives, and catch crops are the measure that farmers primarily use.

Catch crops

Catch crops are used with the aim of limiting nitrate leaching from the root zone. Catch crops are grown before sowing winter crops and absorb excess nitrogen in the soil, reducing leaching. Cultivation of catch crops leads to reduced emissions of indirect nitrous oxide from the leaching and runoff of nitrogen and increased carbon uptake in the soil through the greater amount of plant residues in the field. Nitrous oxide from decomposition of plant residues from catch crops will also marginally increase ammonia emissions.

Climate regulation of field operations
Cultivation practices in the field affect the soil's carbon stock and can thus lead to emissions or removal of CO_2-eq. An increased supply of organic matter in the field, e.g. through increased plant cover or application of organic fertiliser, will lead to a gradual build-up of carbon in the soil. The build-up of carbon will continue until a new equilibrium is reached in the soil carbon stock that corresponds to the new cultivation practices. Carbon storage in arable farming is reversible, which means that if there is a change in cultivation practices towards a lower input of organic matter, carbon storage will gradually decrease. This will lead to CO_2-eq emissions. To avoid this, it is thus necessary to maintain a given cultivation practice. It is estimated that it takes around 20-60 years to achieve a new equilibrium in the soil.

The existing nitrogen regulation uses measures (e.g. catch crops and catch crops) that can increase carbon storage in the soil by increasing the supply of organic material to the field. These measures are used in large areas of the country to reduce nitrogen leaching and also have a climate impact. This climate effect is already included in the climate projection and it is expected that these measures will be maintained until 2030 due to nitrogen considerations.

The CO_2-eq shadow price of a cultivation practice that affects soil carbon stocks must reflect that the effect is diminishing and reversible. This means that any subsidy rate should be reduced to ensure a uniform financial incentive across reversible and irreversible CO_2-eq reductions when all effects and costs over time are taken into account. In addition, maintaining field management measures such as catch crops and intercropping may result in a small net emission of CO_2-eq in the long term due to a permanent emission of nitrous oxide that continues after carbon build-up has ceased.

Field management measures to reduce nitrogen leaching are central to the planned nitrogen regulation, and the Expert Group recommends that climate effects, such as carbon absorption in the soil and nitrous oxide emissions from plant residues, be included in the new regulation. Granting subsidies for field operations may be considered to increase the soil's carbon stock, bearing in mind that the effect is diminishing and reversible. Subsidies for field management measures are included as a possible adjusting screw in *Section 2.6*.

It is possible to derive the optimal ratio between subsidies for measures with a renewable effect and carbon storage measures with a decreasing impact so that a similar shadow price is achieved across the two types of measures. The optimal ratio will depend on the future carbon accumulation and the cost of maintaining the measures discounted according to the socio-economic discount rate. With a subsidy of DKK 429 per tonne of CO_2-eq, it is estimated to provide a CO_2-eq reduction of 0.2 in 2030 with a marginal shadow price of DKK 700 per tonne of CO_2-eq in 2030. As the effect is diminishing, the CO_2-eq reduction is estimated to be 0.1 in 2045 if the cultivation practice is maintained.

Research has been initiated to help improve fertiliser emissions factors so that the overall cultivation practice, including crop selection and management, can be taken into account when calculating the nitrous oxide loss from applied fertiliser. In this way, field operations can eventually be included in the calculation of the farm's emissions and improve the interaction between climate and nitrogen regulation.

Biochar by pyrolysis
Pyrolysis is a process where material is heated under oxygen-deficient conditions, creating a form of incomplete combustion of the material. The pyrolysis process produces a carbon-containing solid product and a pyrolysis gas, which can be converted into a pyrolysis oil when cooled. When biomass is used as an input to the pyrolysis process, the solid fraction is called biochar. Over time, some of the sequestered carbon is rereleased. Still, since only a small portion is expected to be released after 100 years and a large portion of the carbon in biochar is expected to be stored for centuries, biochar is considered to be approximately a long-term store or carbon.
The pyrolysis process also produces energy products in the form of waste heat, pyrolysis gas and potentially pyrolysis oil. It is estimated that the pyrolysis oil will be used in shipping, which is outside the 70 per cent target, and that the gas and excess heat will replace other renewable energy production. It is therefore assumed that pyrolysis oil, gas and excess heat do not lead to CO_2 reductions in the national emissions inventory, but that the pyrolysis plant sells all energy products, which generates revenue for the plant.

Pyrolysis costs are made up of plant investment costs, operating costs, biomass costs and costs associated with the transport and application of biochar. Revenue is generated from the sale of waste heat, pyrolysis gas and pyrolysis oil. Climate credits may also be sold, but these are not included in the technological costs per tonne of CO_2, *see Table 7.10*. The technological costs depend on which biomass is used for production, as well as the amount of biochar produced, as it is estimated to be more expensive the more biomass that must be allocated to biochar production. The technological costs thus amount to DKK 900-3,300 per tonne. However, the socio-economic costs per tonne will be higher, as the CO_2 effect here must be offset by the fact that some of the biomass was a temporary carbon store to begin with.

Biochar can be produced from different biomasses such as straw, biogas digestate and wood waste. However, the technical potential is highly dependent on the phosphorus content of the biomass. If the applied biochar is limited to biochar produced by the total Danish amount of biomass that is currently either applied to agricultural land or incinerated, the total technical potential would be approx. 3.5 million tonnes of CO_2. If only Danish biomass that is currently used on agricultural land is used, the potential is even lower at a total of approx. 1.6 million tonnes of CO_2.

If large amounts of biomass are imported, the potential for biochar application will be very high. For biochar produced on wood, it is estimated that 12 million tonnes of biochar can be applied annually, corresponding to 38 million tonnes of CO_2, while it is estimated that 6 million tonnes of biochar can be applied annually on straw, corresponding to 12 million tonnes of CO_2. For biochar produced on digestate, it is estimated that 0.8 million tonnes of biochar can be applied annually, corresponding to a CO_2 effect of 0.9 million tonnes of CO_2.

Research into the formation and degradation of environmentally harmful substances during biochar production, which is expected to deliver results by the end of 2025, and results from multi-year cultivation trials on the environmental and agronomic effects of spreading biochar on agricultural land, which are expected to be completed in 2033, with annual reports and interim reporting in 2027, are still pending. In addition, a methodology for including biochar in Denmark's emissions inventory has yet to be developed and is expected to be finalised in 2026.

In the short term, the realisation of biochar application is estimated to depend on the possibility of obtaining a permit for large-scale biochar application, which depends on the upcoming research results. In addition, realisation in the short term is estimated to be limited by the expansion of facilities, as there are currently only small demonstration facilities.

7.6 Regulatory Basis and Data

It is assumed that regulatory models for taxes and subsidies in the agricultural and forestry sectors are based on the same data as in the preparation of the emissions inventory, which calculates agricultural emissions, *see Chapter 5*. This appendix describes farm-related data that is included in the preparation of the national emissions inventory, including how it can be included in the regulatory basis that will serve as the foundation for taxes and subsidies in the agricultural area. These are data that farms currently self-report as part of the existing environmental and food regulation under the Ministry of the Environment and the Ministry of Food, Agriculture and Fisheries and emissions factors estimated by the DCE. The chapter should also be read in conjunction with *Appendix 7.4*, which describes the methods used to prepare the national emissions inventory.

The Expert Group has noted that there will be a need to strengthen the control and quality of data sources from existing environmental, food and climate regulation, increase incentives for correct registration in existing registers and adjust the administrative setup if data from these registers are to be used in the implementation of a tax and subsidy system. This is because the current data is designed with other purposes in mind, which requires customisation to ensure reliable and relevant data for the CO_2-eq regulation models.

When assessing the implementation options, *see Chapter 5*, it is assumed that authorities with responsibility for the data used, e.g. from existing environmental and food legislation, are also generally responsible for administrative law obligations, including the declaration process and data corrections.

Farm-related activities and emissions factors

CO_2-eq regulation of the agricultural and forestry sector's non-energy-related emissions must, as a starting point, be based on the systematics and categorisation in the national emissions inventory so that the regulation supports reductions in accordance with the national emission inventory*, see Appendix 7.4*. In this context, it is important that the inventory is continuously developed within the framework of the IPCC guidelines so that new knowledge is taken into account and the effect of new technologies can be reflected.

The DCE's calculation follows the IPCC guidelines, which specify calculation formulas for calculating emissions and contain descriptions of the data that should be collected for this purpose. Emissions are basically calculated by multiplying activity data (AD) by an emissions factor (EF) in the simple formula: Emissions = AD × EF. Activity data is e.g. number of dairy cattle, number of pigs, hectares of carbon-rich agricultural land, amount of fertiliser applied to fields and type of housing. Activity data included in the national emissions inventory is based on the farm-related data that is self-reported as part of existing food and environmental regulation.

The emissions factor for the emitting activities can either be an IPCC standard factor, a country-specific factor or modelled from national data. Emissions factors associated with a given activity can be updated if adjustments are made based on initiatives, such as the development of new technology, that affect the activity or emissions factors. This update takes place in the work on the national emissions inventory. The emissions factors associated with an activity can both be updated generally as a result of new research, but can also be adjusted based on farm-specific conditions. This means that a company's emissions can be affected by, for example, the company using a new, approved technology that affects the emissions from a given activity in relation to the standard emission in accordance with the emission inventory, *see Appendix 7.4*. The basis for subsidies for technologies that are not currently included in the national emissions inventory is described in *Appendix 7.5*.

The basis for regulation can be based on the existing reporting of activities, while at the same time work is initiated to increase the scope and quality of reporting, administration and control, *see Chapter 5*. This will meet a consideration that the tax and subsidy base should follow the calculation of emissions associated with a given activity in the emissions inventory, *see Appendix 7.4*.

Data

The following sections describe data that is assumed to be used as a basis for regulating emissions from livestock. Examples include cattle and pigs, fertiliser applied to fields, field management and carbon-rich agricultural land. For other livestock, the systematisation will be comparable to cattle and pigs. Emissions from livestock can be attributed to 1) emissions from animal digestion, 2) emissions from animal manure in stables and storage facilities, *see Appendix 7.4*.

Livestock (emissions from digestion processes)

Registering data on cattle

The emissions inventory's unique variations (type and subtype) for cattle are registered in the fertiliser accounts*, see Table 7.11.* Cattle are registered in the fertiliser accounts in the number of animals produced per year, corresponding to the count in the emissions inventory.

Table 7.11. Variations for cattle emissions from digestion in the emissions inventory, including data sources in existing environmental and food legislation

Type	Subtype	Emissions factor, tonne of CO_2-eq per animal[1]	Data source for subtype
Dairy cows	Dairy cows, jersey	3.79	Fertiliser accounts
	Dairy cows, heavy breed	4.61	Fertiliser accounts
Suckler cows	Suckler cows <400 kg	1.23	Fertiliser accounts
	Suckler cows >600 kg	2.02	Fertiliser accounts
	Suckler cows 400-600 kg	1.78	Fertiliser accounts
Cattle for breeding	Breeding, 0-6 months, jersey	0.47	Fertiliser accounts
	Breeding, 0-6 months, heavy breed	0.63	Fertiliser accounts
	Breeding, >6 months - calves, jersey	1.19	Fertiliser accounts
	Breeding, >6 months - calves, heavy breed	1.59	Fertiliser accounts
Veal calves	Veal calves, 0-6 months, jersey	0.26	Fertiliser accounts
	Veal calves, 0-6 months, heavy breed	0.18	Fertiliser accounts
	Veal calves, >6 months - 328 kg, jersey	0.47	Fertiliser accounts

	Veal calf, >6 months - 440 kg, heavy breed	0.34	Fertiliser accounts

Note: It is the type and subtype that is registered farm by farm in the fertiliser accounts. The emissions factor is calculated as part of the emissions inventory and is therefore not included in the fertiliser accounts. The emissions inventory is prepared on the basis of reports from the fertiliser accounts. 1) These are emissions factors based on data for emissions from 2021. Emissions factors change continuously as part of the work on the national emissions inventory, which is published annually.

Registration of data on pigs

All the unique variations (type and subtype) of pigs in the emissions inventory are registered in the fertiliser accounts*, see Table 7.12*. Pigs (fattening pigs, piglets and yearling sows) are recorded in the fertiliser accounts as the number of animals produced per year, corresponding to the count in the emissions inventory.

Table 7.12. Variations for pigs' emissions from digestion in the emissions inventory, including data sources in existing environmental and food legislation

Type	Subtype	Emissions factor, tonne of CO_2-eq per animal[1]	Data source for type/subtype
Pigs	Fattening pigs, 31-115 kg	0.01	Fertiliser accounts
	Piglets, 6.7-31 kg	0.00*	Fertiliser accounts
	Yearling sows	0.08	Fertiliser accounts

Note: It is the type and subtype that is registered farm by farm in the fertiliser accounts. The emissions factor is prepared as part of the emissions inventory and thus does not appear in the fertiliser accounts. *0.00 means that emissions do not appear at the 2nd decimal place. There are still emissions. 1) These are emissions factors based on emissions data from 2021. Emissions factors change continuously as part of the work on the national emissions inventory, which is published annually.

Livestock (emissions from fertiliser management in stables and storage)

Types of housing are crucial for variations in emissions factors for emissions from fertiliser management in the stable and at storages from cows and pigs. Types of housing refer to different flooring and fertiliser systems in the stable. *Table 7.13* shows a sample of selected types of housing and subtypes of livestock. In total, there are over 100 variations in the emissions inventory for emissions from types of housing for cattle and pigs across different animal types. Data on types of housing are registered farm by farm in the fertiliser accounts.

Table 7.13. Table with selected variations on emissions from types of housing for cattle and pigs

Type	Subtype	Emissions factor, tonne of CO_2-eq per animal[1]	Data source for type/subtype
Dairy cows, heavy breed	Deep bedding (entire area)	4.62	Fertiliser accounts
	Deep bedding, solid floor, scraper	2.23	Fertiliser accounts
	Deep bedding, slatted floor, flush/channel	2.23	Fertiliser accounts
	Deep bedding, slatted floor, scraper	2.23	Fertiliser accounts
	Tied-stall w/ floor grating	1.67	Fertiliser accounts
	Cubicles, solid floor, scraper	1.56	Fertiliser accounts
	Cubicles, slatted floor, flush/channel	1.56	Fertiliser accounts
	Cubicles, slatted floor, scraper	1.56	Fertiliser accounts
	Cubicles w/ solid floor, 2 per cent slope, scraper	1.56	Fertiliser accounts
	Biogasified slurry system	1.08	Fertiliser accounts
	Tied-stall w/ gutter	0.39	Fertiliser accounts
Fattening pigs, 31-115 kg	Deep bedding	0.09	Fertiliser accounts
	Partially slatted floor (50-75 per cent solid floor)	0.04	Fertiliser accounts
	Partially slatted floor (25-49 per cent solid floor)	0.04	Fertiliser accounts
	Drained floor + slatted floor (33/67)	0.04	Fertiliser accounts
	Divided rental area	0.03	Fertiliser accounts
	Biogasified slurry system	0.03	Fertiliser accounts
	Solid floor	0.01	Fertiliser accounts

Note: It is the type and subtype that is registered farm by farm in the fertiliser accounts. 1) These are emissions factors based on data for emissions from 2022. Emissions factors change continuously as part of the work on the national emissions inventory, which is published annually, and are therefore not included in the fertiliser accounts.

In addition to types of housing, there are a number of stable and storage technologies that reduce greenhouse gas emissions on the individual farm, such as slurry cooling, frequent removal, delivery to biogas, acidification, flaring and covering of slurry tanks, etc. This is described in *Appendix 7.5*. It should be noted that these technologies are not included in the emissions inventory today, as the climate effects are not sufficiently documented. However, most of the mentioned stable and storage technologies are included in the Climate Status and Outlook, as there is deemed to be sufficient documentation for the DCE to be able to recognise the effects in 2027. Some of the technologies are currently used to reduce ammonia emissions in agriculture.

Barn and storage technologies are not currently registered in the fertiliser accounts or in other registers in the environmental area. It is assumed that these will be included in the regulatory basis when the necessary registration is provided.

Fertiliser applied to fields in kg nitrogen

Emissions from fertiliser applied to fields are calculated based on how many kilograms of nitrogen are in the fertiliser applied to agricultural land. Some of the nitrogen in the fertiliser is converted into nitrous oxide, which is a greenhouse gas.

A tax on nitrous oxide emissions from fertiliser applied to fields can be based on how many kg of nitrogen is applied annually to the individual farms' land, *see Table 7.14.* According to current regulations, this is already registered. The farmer reports information in the fertiliser accounts about how many kg of nitrogen is applied annually to the farm's land. The requirement for balance between farmers' nitrogen quota and nitrogen consumption is covered by the rules on conditionality and cross-compliance. Violation of the requirement will thus result in an administrative sanction in relation to the payment of agricultural subsidies.

Table 7.14. Data sources in existing environmental legislation for applied fertiliser (kg N)

Type/subtype	Emissions factor	Data source for type/subtype
Fertiliser applied to the field (kg N)	4.2 tonnes of CO_2-eq per tonne N applied to fields	Fertiliser accounts

Note: It is the type and subtype that is registered farm by farm in the fertiliser accounts. The emissions factor is calculated as part of the emissions inventory and is therefore not included in the fertiliser accounts. This is an emissions factor based on data for emissions from 2022. Emissions factors change continuously as part of the work on the national emissions inventory, which is published annually.

In the emissions inventory, emissions from fertilisers are calculated based on an emissions factor of 4.2 tonnes of CO_2-eq per tonne of nitrogen applied to fields, regardless of whether livestock manure, non-organic fertiliser or other types of organic fertiliser are applied.

A tax on how much fertiliser (in kg nitrogen) the individual farm applies to its fields annually, based on the emissions factor, will target the calculation of Denmark's 70 per cent target but will not take into account the variation in CO_2-eq emissions from fertiliser applied to fields, e.g. as a result of use in connection with plant production. It is expected that the emissions factor will eventually differentiate the emissions factor between livestock manure, non-organic fertiliser and other organic fertilisers.

Carbon-rich agricultural land

A regulatory basis for carbon-rich agricultural land in agriculture can be prepared by an overlap analysis of the so-called carbon map (Peat 2022) and the cultivation map (IMK), which is used in connection with the payment of the hectare subsidy. Such an overlap analysis already forms the basis for the regulation of the current voluntary efforts to set aside carbon-rich agricultural land and the calculation of emissions from carbon-rich agricultural land in the national emissions inventory.

Today, there are no existing data and registers that contain a farm-specific inventory of the amount of carbon-rich agricultural land. Thus, an independent regulatory basis will have to be prepared, which is described in *section 3.1* as part of the Expert Group's models for regulating emissions from carbon-rich agricultural land.

The emissions factors from the emissions inventory for different types of carbon-rich agricultural land in agriculture are shown in *Table 7.15*. Emissions are reduced upon wetland restoration.[47] After wetland restoration, there is still a minor CO_2-eq emission, which comes from an increase in methane emissions.

Table 7.15. Emissions from carbon-rich agricultural land in agriculture and data source

Type	Emissions factor[1]	Data source for type
Units	*Tonne of CO_2-eq per hectare*	
Cultivated land (agricultural land), 6-12 per cent	25.2	Overlap analysis between the so-called carbon map (Peat 2022) and the cultivation map (IMK)
Cultivated land (agricultural land), > 12 per cent	50.3	
Permanent grazing land, 6-12 per cent	18.7	
Permanent grazing land, > 12 per cent.	37.4	

Note: This is an emissions factor based on data for emissions from 2022. Emissions factors change continuously as part of the work on the national emissions inventory, which is published annually.
Source: DCE, Scientific note 2024 60.

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[47] Rewetting means that the natural water level is restored and the land can become a kind of wetland. In practice, there are soils where restoring the natural water level means that there are periods when the soil is not under water.

7.7 ETS in Agriculture and Forestry

The terms of reference of the Expert Group state that:

"*The second report will also assess the advantages and disadvantages of a regulatory solution for the agricultural sector, a subsidy model for EU agricultural support and a CO_2-eq tax for this sector or a combination of these, as well as possible measures for cost-effective regulation of agriculture that address CO_2-eq emissions and other externalities, including, e.g. environment and health*."

As stated in the summary and models section, the Expert Group has chosen to present models where tax and subsidies are combined in order to fulfil climate targets and EU obligations. As part of this work, the Expert Group has considered whether an ETS within agriculture (which may also include forestry) would be a more appropriate tool to fulfil Denmark's climate goals. In an ETS with tradable allowances, the state issues a number of allowances that entitle the right to emit a certain amount of CO_2-eq and allows companies to trade the allowances among themselves.

After weighing up the advantages and disadvantages of an ETS for agriculture, the Expert Group has chosen *not* to present such a system in the models in *Chapter 2*.

The main *benefits of* an ETS are as follows:

1) An ETS allows for precise control of total emissions from agriculture. It is an advantage if there is a political requirement for agriculture to reduce emissions by a certain amount within a given timeframe. With a CO_2-eq tax, there is not the same certainty of achieving a specific reduction.

2) An ETS offers the opportunity to reduce the burden on the agricultural sector and associated capital losses of climate regulation through some free allocation of allowances.[48] This can reduce the need for other and potentially more complicated compensation schemes.

An ETS, on the other hand, has the following *disadvantages*:

3) Under an ETS, it is difficult to align the price of agricultural CO_2-eq emissions represented by the allowance price with the CO_2 tax for other industries outside the EU ETS. This is a problem if there is a political desire for a uniform CO_2-eq price for all industries.

4) Unpredictable fluctuations in the price of allowances over time will increase uncertainty about the profitability of investments in more climate-friendly technologies. This is not the case under a tax system where the development of the tax is fixed in advance.

5) A compensation scheme in the form of free allocation of allowances is challenging to design without creating either discrimination between current and

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[48] However, an ETS with free allowances will basically work in the same way as a tax system with a base deduction.

future generations of farmers, weakened incentives to reduce emissions or possibly undesirable redistributions within the agricultural industry that would require additional compensation schemes.

In the Expert Group's assessment, the disadvantages 3), 4) and 5) of a separate national ETS for agriculture outweigh the advantages 1) and 2).

However, the Expert Group is aware that the European Commission is considering the possible introduction of an EU ETS for agriculture. A significant advantage of such a common climate regulation is that it will put Danish agriculture on an equal competitive footing with agriculture in the rest of the EU, thereby avoiding distortions in agricultural production. The models presented by the Expert Group, which do not introduce a separate Danish ETS for agriculture, should, therefore, not be interpreted as a rejection of a possible future pan-European ETS for agriculture. The Expert Group notes that the preparation of the administrative basis for a Danish climate tax on agriculture will probably contribute to the future implementation in Denmark of a common EU ETS for agriculture, should such a system be adopted.

The Expert Group's considerations on an ETS for agriculture are elaborated in the following.

ETS versus tax system: Similarities and differences

In a theoretical world with perfect information exactly the same CO_2-eq price and the same amount of emissions can, in principle, be achieved with a tax system as with a system with tradable CO_2-eq allowances. Under complete information, the authorities can calculate the exact amount of emissions resulting from a given tax rate, just as they can calculate the precise price of allowances resulting from a given allowance supply. This will allow authorities to implement exactly the same CO_2-eq price and emissions in the two systems.

However, in the real world, with uncertainty about companies' cost and market conditions, there will be uncertainty about how high emissions will be at a given CO_2-eq tax rate, while under an ETS there will be uncertainty about what quota price will be formed at a given quota supply.

An ETS with a liquid market for tradable allowances, like a tax system, can deliver cost-effective reductions in greenhouse gas emissions from the sector covered by the allowances, as the price of allowances establishes a uniform price on emissions for all covered production units. Through the determination of the supply of allowances, the state can precisely control the amount of emissions from the sector, which in principle provides full certainty that the desired reductions will be achieved.

In contrast, the price of allowances cannot be perfectly controlled as there is uncertainty about the cost to producers of reducing their emissions and, thus, uncertainty about the demand for allowances. With a separate ETS for agriculture, it is therefore difficult to standardise the price of CO_2-eq across sectors in combination with e.g. the CO_2-eq tax on industry, etc. The purpose of a uniform CO_2-eq tax is to ensure that CO_2-eq reductions are made where it is cheapest, both within and across sectors. If agriculture is regulated separately through an ETS and the price of allowances differs from the CO_2-eq tax for industry, the same degree of cost efficiency that a common, uniform CO_2-eq tax for industry and agriculture would create is not achieved, as the marginal reduction costs are not equalised across sectors. However, if politicians want to operate with a different CO_2-eq price for agriculture than for other sectors, this argument against a separate ETS for agriculture naturally carries less weight.

Another problem, however, is that the CO_2-eq price can fluctuate significantly over time under an ETS due to uncertainty about the cost to producers of reducing their emissions and because, for example, fluctuations in the prices of agricultural products can cause fluctuations in the price of allowances. These uncertainties mean that the incentives to invest in climate-friendly technologies may be lower under an ETS than under a tax system, *see box 7.5*.

Box 7.5

Examples of investments in technologies under an ETS in agriculture

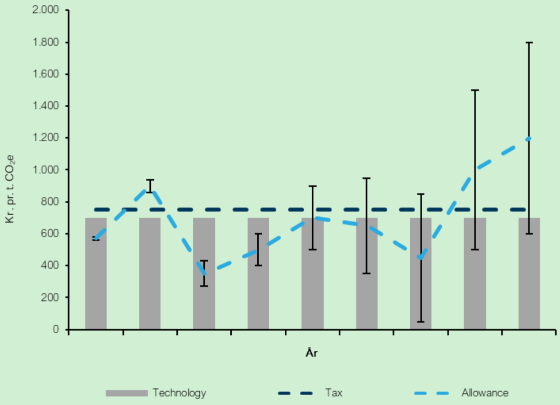
In an ETS, the price of allowances can vary from year to year, whereas the price of a CO_2-eq tax is fixed. Below are two stylised examples of a technology that is invested in annually and a technology that requires a longer-term investment.

For a technology where the farmer has to decide annually whether to use the technology, e.g. feed additives, the implementation of the technology under an ETS will depend on the relative prices of allowances and the specific technology. With a tax system, the implementation of a given technology will depend on the technology price in the given year. In both cases, the farmer will assess each year whether or not it is profitable to invest in the technology. The figure below illustrates an example where the price of a given technology is fixed year on year. Under an ETS, the farmer will only invest in the technology in years where the price of allowances exceeds the price of the technology, whereas under a tax system, the farmer will invest in the technology every year, provided the tax is higher than the cost of implementing the technology.

The investment decision will depend on the farmer's long-term expectations of relative prices for a technology that requires a longer-term investment, such as technologies for stables. Under an ETS, the investment decision depends on the farmer's expectations for the development of the price of allowances and how much risk the farmer wants to take on. In a tax system where the future tax rate is predetermined, the uncertainty about the future CO_2-eq price is removed and the farmer only has to assess whether it is profitable to invest in the technology based on his knowledge of the investment cost and the expected future operating costs of using the technology.

Overall, a tax system can thus provide more favourable incentives for investment in climate-friendly technologies than an ETS.

Example of technology costs relative to allowance price and tax level



Note: Range indicates uncertainty in price. Uncertainty increases the further into the future it is.

The design of an ETS

In its purest form, an ETS works by the state auctioning allowances to companies, which are then authorised to emit a given amount of CO_2-eq. Companies can then trade allowances among themselves as needed after the initial auction round. The state receives revenue from the sale of allowances, which can be used to compensate emitters, for general tax or duty relief, or for increased public spending.

The rules for the use of allowances can be designed in two main ways that will affect companies' incentives differently, *see Box 7.6*.

Box 7.6

Design of the EU ETS

Time-limited allowances
The allowances expire after a given period of time, e.g. one year, after which a new allowance period starts. If the allowances expire after a given time period and are subsequently worthless, it creates certainty to achieve a given volume reduction within that time period. This will create certainty in relation to political reduction targets, such as the 70 per cent target.

On the other hand, there will be uncertainty about the price of CO_2-eq in this ETS, as there may be large variations in the demand for allowances both within the individual allowance period and across allowance periods, e.g. due to fluctuations in weather conditions.

Allowances that can be saved up
Alternatively, you can allow allowances to be "saved up" for later use. This can reduce short-term fluctuations in the price of allowances, as companies can choose to bank allowances in years when the price of allowances is relatively low and use banked allowances in years when the price of allowances is particularly high. Such a system gives the companies the opportunity to make a larger share of the reductions this year when the reduction efforts are relatively cheap, thereby reducing the present value of the total reduction costs over time. An ETS with the option to bank allowances does not guarantee the achievement of a given reduction in any given year, but still ensures a certain amount of reductions within the time horizon over which banked allowances can be utilised. Even if allowances can be utilised in perpetuity, there will still be a guarantee that total emissions over time cannot exceed the total amount of allowances issued over time. However, there will be no certainty that a specific amount of reductions will be achieved in a given future year, such as 2030.

An ETS with free allowances

If the government wants to reduce the immediate business burden of the ETS, it can choose to allocate some or even all of the issued allowances to companies free of charge. This reduces the need for other forms of compensation to companies, as the allocation of free allowances is equivalent to handing out financial assets with a market value equal to the price of allowances.

The extent of the allocation of free allowances can be gradually phased out over time to the extent that there is a political will to enforce the polluter pays principle.

The distributional consequences of such a system will depend on the criteria for allocating free allowances. In the following, various possible criteria are discussed.

Allowance allocation based on historical emissions
In an ETS for agriculture, allowances could be allocated according to the farms' historical emissions from land and livestock. A fixed free allowance allocation that is independent of the company's current production means that the price of allowances is fully reflected in the companies' marginal costs. Thus, it is a question of compensation for the farmer, which does not affect the farmer's production decision. In this way, the farmer's full incentive to reduce their emissions is maintained. For example, at the margin, livestock producers will have the same

incentive to reduce livestock numbers as if the allowance were auctioned by the state.

It is essential that the allocation of allowances is based on a criterion such as historical emissions that is not influenced by the current behaviour of companies, so that individual companies do not risk having the allocated amount of free allowances reduced if they reduce their emissions after the introduction of the system. Otherwise, companies that implement reduction measures will fear that their free allowance will be reduced in the long run, thereby weakening the incentive to transition.

However, a system of free allowances based on historical emissions may be less efficient than a system based on auctioning allowances, as more efficient farmers with increasing production will have to buy allowances from less efficient farmers with decreasing production. This will result in an economic redistribution in favour of the latter group, which can hamper the industry's productivity development. A particular problem is that farmers who set up after the introduction of the ETS cannot be allocated free allowances on the basis of historical emissions, so special allocation criteria must be designed for this group to avoid discriminating against new generations of farmers.

In addition, there may be administrative and control challenges when calculating the historical emissions of the individual farms.

Allowance allocation based on the farm's production
Within the EU's emissions trading system (ETS) for the energy sector and the energy-intensive industry, allowances are allocated free of charge to companies in certain industries exposed to competition, such as steel and cement, where there is considered to be a particularly high risk of leakage of CO_2 emissions to countries outside the EU. The allocation of free allowances to each company is proportional to the company's production over a certain previous period multiplied by an emissions factor that reflects the average CO_2 intensity (CO_2 emissions per unit produced) of the 10 per cent of companies in the industry with the lowest CO_2 intensity. Under this system, an increase in a company's production will, with a certain delay, trigger an increase in the company's allocated amount of free allowances, which in isolation strengthens the company's competitiveness and counteracts the structural effects (the fall in production) caused by the ETS. At the same time, the individual company's incentive to lower its CO_2 intensity through technical conversion of production (thereby freeing up allowances that can be sold on the market) is preserved, as the individual company has no significant influence on the average CO_2 intensity that forms the basis for the allocation of allowances.

However, a similar system for allocating free allowances in a national quota system for agriculture would probably result in a very high allowance price if the climate targets are to be met, *see Box 7.7*. As the box explains, free allocation of allowances on the basis of individual farm's production will severely weaken the incentive to reduce emissions when emissions are highly correlated with production due to limited technological possibilities to lower emissions per unit produced. The Expert Group's analyses indicate that the technical possibilities for lowering the emission intensity of Danish agriculture at affordable reduction costs are so far limited and that it is, therefore, not realistic to meet Denmark's national climate targets and international climate commitments without some reduction in agricultural production. A system of free allocation of allowances based on production will inhibit the necessary production adjustment, which means that the price of allowances must be pushed up very high to ensure the necessary greenhouse gas reductions. A disproportionately high CO_2-eq price in agriculture compared to the CO_2-eq tax on other industries will make climate action less cost-effective. A free allocation of allowances based on the individual farm's production may therefore be inappropriate.

Box 7.7

Free allocation of allowances based on the individual farm's production

A simplified example can illustrate the potential problem of allocating free allowances to each farm based on the farm's production.

Consider a dairy farmer who owns K dairy cattle, each producing q litres of milk per year, so the farm's total annual production is $q \times K$. Assume that the average emission per dairy cow in total agriculture is estimated to be u based on Denmark's emissions inventory, and that the dairy farmer in question is allocated a quantity $Q = k \times u \times q \times K$ of free allowances, where k is a proportionality factor common to all producers and $u\, q \times K$ is the emissions that the dairy farm would have if its production had the average greenhouse gas intensity u. Furthermore, assume that you are in the ideal situation where you can measure the actual greenhouse gas intensity u_f from the farm in question. If the allowance price is p, the ETS will then impose a total net payment N on the farm of the size

$$N = (p \times u_f \times q \times K) - (p \times k \times u \times q \times K) \tag{1}$$

where the term in the first parenthesis on the right-hand side of equation (1) is the farm's cost of purchasing allowances in the absence of free allocation of allowances, and the term in the last parenthesis is the market value of the free allocated allowances, which depends on the allowance price p. If the dairy farmer is able to reduce the farm's emission intensity by the amount du_f, e.g. via feed additives, it follows from (1) that his net payment will decrease by the amount $du_f \times p \times q \times K$, since the amount of free allowances allocated to the farm will remain unchanged. Thus, the free allocation does not weaken the incentive to reduce emissions through technical reduction measures.

If the farm instead lowers its emissions by lowering the cattle population by the amount dK, the change dN in the farm's net payment according to (1) will be

$$dN = (u_f - k \times u) \times p \times u \times q \times dK \tag{2}$$

According to (2), compared to an ETS without free allocation of allowances, where $k = 0$, free allocation will reduce the decrease in the farm's net payment and thus weaken the incentive to reduce emissions by reducing the effort of the production input (in this case cattle) that is the source of emissions.

The example illustrates that if there are only limited technical possibilities to reduce emission intensity and thus a high degree of proportionality between production and emissions, a system of free allowance allocation on the basis of the individual farm's production can weaken the incentive for greenhouse gas reductions to such an extent that it will require a very high allowance price to achieve the targeted reductions. The issue is exacerbated if it is difficult in practice to measure the actual emission intensity (u_f) on the individual farm, as this will reduce the individual farmer's incentive to implement technical reduction measures.

Allowance allocation per hectare of land

Another option is to allocate free allowance proportional to the area of the individual farm. This would be administratively simple, as the area of farms is already calculated in connection with the payment of the hectare subsidy under the EU's Common Agricultural Policy. Furthermore, an allowance allocation based on hectares will not reduce or distort farmers' incentives to implement reduction measures, as these will not affect the allowance allocation.

An allowance allocation per hectare of land that applies to both current and future landowners will counteract the decline in land values that would otherwise occur in an ETS without free allowances. This may be a desired effect in terms of limiting the number of bankruptcies and the resulting pressure on financial stability in connection with a future climate regulation of agriculture. However, the counterpart to capitalising the value of free allowances in land values is that these can become more volatile due to fluctuations in the price of allowances.

By linking the free allocation of allowances to the area and continuing the free allocation when ownership changes, the system avoids favouring current farmers over future generations of farmers. This equality of current and future farmers is a favourable feature of the area criterion compared to a system where free allowances are allocated based on historical emissions.

However, unlike an allocation based on historical emissions, an allocation based on area will have more significant distributional consequences within the current generation of farmers, as the area criterion will favour producers with large areas over producers with more limited areas. In particular, livestock farms with high emission intensities will be less favoured by using the area criterion. If you politically want to counter this redistribution effect, you could choose to supplement an allowance allocation based on area with an allowance allocation per animal, which could work in the same way as a base deduction per animal, as described in *Chapter 2.* This will help reduce the redistributive effect of an allowance allocation per hectare and maintain the incentive at the margin to use technological solutions, but it will still be difficult to control the CO_2-eq price.

It should be noted that an allocation of free allowances based on the area of the farm in an ETS will work in the same way as a base deduction based on area in a tax system.

State aid law issues

When assessing whether a possible ETS is covered by the state aid rules, it will have to be assessed whether the introduction of such a system may involve state aid in relation to companies that the ETS does not cover, are allocated proceeds from the system, or are allocated free allowances that the company can subsequently trade.

In the variants of a Danish ETS for agriculture discussed above, it is assumed that any allocation of free allowances is not limited to selected agricultural subsectors, but is extended to all farms above a certain size according to one of the three criteria discussed above. Thus, the issue of state aid law concerns whether these systems for free allocation of allowances will be considered to distort competition within the EU's internal market, even though they are only intended as (partial) compensation for the burden on Danish agriculture that a national ETS would constitute.

7.8 Carbon Leakage

The terms of reference state that the Expert Group must consider greenhouse gas leakage (carbon leakage), including the consideration in the Danish Climate Act, to ensure that Danish CO_2-eq reduction measures do not simply move greenhouse gas emissions outside of Danish territory. In general, climate actions that result in CO_2-eq reductions due to structural changes can be associated with carbon leakage. For this reason, carbon leakage in agriculture caused by a CO_2-eq tax should be compared with alternative reduction measures that may also cause carbon leakage.

This section describes the Expert Group's work on carbon leakage in agriculture, including the risk of carbon leakage through the modelling of greenhouse gas emissions from agriculture.

No conclusion is drawn on the exact size of the risk of carbon leakage, as there is a high degree of uncertainty associated with the calculations. Instead, different estimates of carbon leakage under different assumptions are presented.

Chapter 2 presents three different designs of tax systems that reflect the weighting of low socio-economic costs against considerations of limited carbon leakage and limited structural changes in agriculture. This section describes the overall risk of carbon leakage in each of the models included in *chapter 2.* It is estimated that a lower tax level will result in a lower carbon leakage rate if the subsidy for technological reductions is increased so that the technical share for a given CO_2-eq reduction is increased.

Background on greenhouse gas leakage from the first interim report

As described in the first interim report, greenhouse gas leakage refers to a situation where domestic measures aimed at reducing greenhouse gas emissions in Denmark lead to increased emissions abroad, e.g. if part or all of the production of a given product is moved abroad. This means that Danish climate policy measures potentially reduce global emissions less than Danish emissions are reduced.

This effect can be calculated as a carbon leakage rate, which indicates the proportion of domestic CO_2-eq emissions that are replaced by foreign emissions for a given measure. Carbon leakage can, for example, occur through foreign trade by making Danish production of goods with a high climate footprint more expensive as a result of a CO_2-eq tax, which can weaken the competitiveness of Danish producers and lead to Danish and foreign consumers shifting their consumption from goods produced in Denmark to goods produced abroad.

In what follows, a decomposition is reviewed that illustrates that the results for the carbon leakage effects in Danish agriculture are very sensitive to which assumptions are used as a basis for the calculations. Next, the assumptions that are considered to have a significant impact on the size of the carbon leakage rate are analysed.

Decomposition of the carbon leakage effect of a CO_2-eq tax on agriculture

The following shows step-by-step calculations of the leakage effects for Danish agriculture of an exemplified CO_2-eq tax of DKK 750 per tonne on fertiliser usage, liming and livestock, including subsidies for afforestation and other measures, as well as the harmonisation of the tax on F-gases to DKK 750 per tonne of CO_2-eq and the set-aside of carbon-rich agricultural land, *see Figure 7.1,* and broken down by industry level, *see Table 7.16*, where the assumptions that are expected to affect the carbon leakage rate in Danish agriculture are gradually changed. The calculations show, among other things, that the results for carbon leakage effects are very sensitive to assumptions about the production's greenhouse gas intensity, i.e. emissions in relation to value added, in agriculture in Denmark and abroad. In the following, each step of the decomposition is summarised, and *Box 7.8* elaborates on each step.

Step 1: Step 1 assumes that the greenhouse gas intensity of Danish agriculture is the same as abroad and that Danish production is replaced 1:1 by foreign production. A 100 per cent carbon leakage rate would mean, among other things, that there are no technological reduction options in agriculture.

Step 2: When other effects[49] are included, the carbon leakage rate drops from 100 per cent to 52 per cent, which is due to the fact that technical effects lead to significant CO_2-eq reductions at a tax of DKK 750 per tonne of CO_2-eq.

Step 3: Carbon leakage rates can be broken down into a combination of direct carbon leakage and indirect carbon leakage. In step 2, only direct carbon leakage is taken into account, i.e. how much of the emissions directly move from Danish agriculture to foreign agricultural sectors. The indirect carbon leakage shows the general equilibrium effects that may occur, including industry shifts and reduced return on capital in Denmark as a result of the tax. For this reason, indirect carbon leakage is taken into account in step 3, reducing the carbon leakage rate to 37 per cent.

Step 4: Steps 4a and 4b look at how different assumptions regarding the relative greenhouse gas intensity of Danish agriculture compared to other countries affect the carbon leakage rate. In step 4a, it is assumed that Danish agriculture has a lower greenhouse gas intensity than foreign agriculture, resulting in a carbon leakage rate of 44 per cent. In step 4b, it is assumed that Danish agriculture has a higher greenhouse gas intensity than abroad, which reduces the carbon leakage rate to 22 per cent.

Step 5: In this step, the carbon leakage rate in GreenREFORM is calculated with leakage coefficients from GTAP-E[50], where it is assumed that EU countries will fulfil binding limits for their emissions in the part of the industry that are not currently regulated under the Effort Sharing Regulation sector, while there are no limits for emissions from non-EU countries In addition, substitution away from consumption of foods with a high climate footprint is taken into account. The carbon leakage rate is then reduced to 21 per cent.

Thus, the Expert Group assesses that the carbon leakage rate of a CO_2-eq tax on Danish agriculture is significantly less than 100 per cent, as it is expected that the tax will drive technical change and lead to general equilibrium effects. For this reason, the leakage rate is based on steps 3-5, where it is estimated that the carbon leakage rate in agriculture is between 21-44 per cent, corresponding to 21-44 per cent of the reductions from a CO_2-eq tax of DKK 750 per tonne of CO_2-eq on agriculture resulting in carbon leakage, *see Figure 7.1 and Table 7.16*.

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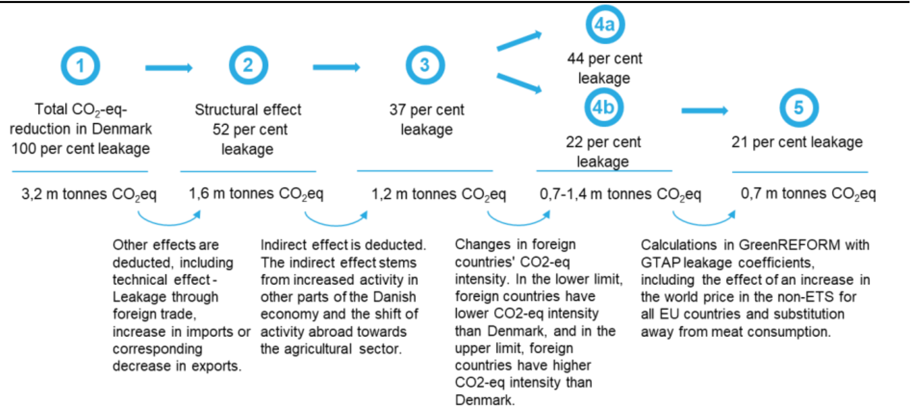
[49] Other effects include technical effects (reductions that do not affect the scope of production but reduce emissions per unit produced, e.g. via feed additives for cattle, biochar in pyrolysis, etc.) and activity effects (e.g. change from farmland to forest or carbon-rich agricultural land being flooded).

[50] The GTAP model is a model of global trade that describes bilateral trade patterns, production, consumption and intermediate use of goods and services. GTAP-E is an extended model that includes energy consumption and CO_2-eq emissions and can be used to determine carbon leakage rates.

Figure 7.1. Decomposition of carbon leakage effects in agriculture at a CO_2-eq tax of DKK 750 per tonne



Note: For each step, a single component changes from the previous calculation. For example, steps from 3 to 4a assume that Danish agriculture has a lower CO_2-eq intensity than abroad for similar production, but still take into account price pass-through in agricultural goods. Greenhouse gas intensities for the lower estimate (4a) come from Lesschen et al. (2011), while the upper estimate (4b) assumes that agriculture in the rest of the world is 42 per cent less greenhouse gas intensive than Danish agriculture in 2030, as assumed in the 2020 report from the Danish Environmental Economic Council (DMØR).
Source: Own calculations

The decomposition of the carbon leakage effect can also be done at industry level, *see Table 7.16*. In *step 2*, it can be seen that the technical effects have the greatest impact on the carbon leakage rate for cattle, which is mainly due to the cattle producers' ability to apply CO_2-eq-reducing measures.

Table 7.16. Changes in foreign emissions and carbon leakage rates in model 1 by agricultural sectors (2030 effects)

	Step 1: Immediate effect	Step 2: Structural effect	Step 3: After indirect effects	Step 4a: Higher CO_2-eq-intensity abroad	Step 4b: Lower CO_2-eq-intensity abroad	Step 5: Restrictions on emissions in the EU etc.
	Million tonnes of CO_2-eq (Carbon leakage rate in per cent)					
Crop	0.4 (100)	0.3 (67.7)	0.2 (48.8)	0.2 (57.1)	0.1 (28.3)	0.1 (25.3)
Cattle	1.8 (100)	1.0 (56.1)	0.7 (40.4)	0.8 (47.3)	0.4 (23.4)	0.4 (23.7)
Pigs	0.5 (100)	0.3 (62.2)	0.2 (44.8)	0.3 (56.51)	0.1 (26.0)	0.1 (21.4)
Other measures	0.4 (100)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Overall	**3.2** **(100)**	**1.6** **(51.6)**	**1.2** **(37.1)**	**1.4** **(44.1)**	**0.7** **(21.5)**	**0.7** **(20.5)**

Note: The effects in 2030 of introducing a CO_2-eq tax of DKK 750 per tonne of CO_2-eq (2022 prices) on fertilisers, liming and livestock and introducing subsidies for afforestation. Changes in foreign emissions are stated in million tonnes of CO_2-eq and rounded to the nearest 100,000 tonnes. The total emission changes do not necessarily match the sum of the individual categories due to rounding. Other measures include a tax on F-gases and the set-aside of carbon-rich agricultural land. A tax on F-gases and the rewetting of carbon-rich agricultural land will lead to reductions of 0.1 and 0.3 million tonnes of CO_2-eq in 2030, respectively, which are assumed to be 100 per cent technical and

activity effects that are therefore not replaced by emissions abroad.
Source: Own calculations

Box 7.8

Description of the decomposition of the carbon leakage effect

Step 1: As a starting point, it is assumed that the greenhouse gas intensity of Danish agriculture is the same as abroad and that Danish production is replaced 1:1 by foreign production. A 100 per cent carbon leakage rate would mean that there are no technological reduction options in agriculture, and the total decrease in emissions of 3.2 million tonnes of CO_2-eq from a CO_2-eq tax on agriculture of DKK 750 per tonne and other measures would consist solely of structural effects. However, this is considered to be an unrealistic scenario, as it is expected that agriculture will use technological measures at a CO_2-eq tax of DKK 750 per tonne.

Step 2: When other effects, including technological measures and activity effects, are included, the carbon leakage rate drops from 100 per cent to 52 per cent, which is due to the fact that other effects amount to approx. 1.5 million tonnes of CO_2-eq within the individual agricultural industries, *see Chapter 2*. For this reason, structural effects will amount to 1.6 million tonnes of CO_2-eq at a CO_2-eq tax of DKK 750 per tonne. Thus, it is the structural effects of the total decrease in emissions that constitute the carbon leakage effect in step 2, and therefore the carbon leakage rate is less than 100 per cent of the total effects. If the effect of rewetting carbon-rich agricultural land is not taken into account, the carbon leakage rate would be 57 per cent.

Step 3: Carbon leakage rates can be broken down into a combination of direct carbon leakage and indirect carbon leakage. In step 2, only direct carbon leakage is taken into account, i.e. how much of the emissions directly move from Danish agriculture to foreign agricultural sectors. The indirect carbon leakage shows the general equilibrium effects that can occur, including industry shifts due to increased activity in other industries in the Danish economy, as capital and labour move from Danish agriculture to other industries, thereby increasing their production and emissions. Conversely, capital and labour abroad move away from other industries and towards the agricultural sector, which lowers production and emissions from other industries abroad. The tax reduces the return on capital in Denmark, which leads to a slight deterioration in global investment opportunities and thus lowers overall global production.[51] The indirect carbon leakage rate is determined based on Beck et al. (2023), who find an indirect carbon leakage rate of -28 per cent.[52] By including this indirect carbon leakage rate, the total carbon leakage rate becomes 37 per cent.

Step 4: Next, we look at how different assumptions regarding the relative greenhouse gas intensity of Danish agriculture compared to other countries affect the carbon leakage rate. Step 4a assumes that foreign agriculture has a higher greenhouse gas intensity than Danish agriculture. Here, greenhouse gas intensities from Lesschen et al. (2011)[53] are used, resulting in a carbon leakage rate of 44 per cent. In step 4b, on the other hand, it is assumed that agriculture abroad has a 42 per cent lower greenhouse gas intensity than Danish agriculture based on 2014 data from the GTAP database, which reduces the carbon leakage rate to 22 per cent. These two assumptions can be considered the extremes of relative greenhouse gas intensity, and for this reason, the carbon leakage rate is expected to be within a range. There is thus considerable variation in the analyses of relative greenhouse gas intensity, and it is not clear which analyses are generally the most accurate in terms of carbon leakage effects, *see Box 7.9*.

Step 5: In this step, the carbon leakage rate is calculated in GreenREFORM, assuming that EU countries will meet binding limits on their emissions in the Effort Sharing Regulation sector, i.e. that EU countries fulfil the Effort Sharing Regulation. In addition, substitution away from consumption of

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[51] The first interim report described how general equilibrium effects can affect leakage effects (https://skm.dk/media/Skatteministeriet/Publikationer/Rapporter/groen-skattereform-foerste-delrapport-tilgaengelig.pdf)

[52] Beck, U. R., Kruse-Andersen, P. K., & Stewart, L. B. (2023), *"Carbon leakage in a small open economy: The importance of international climate policies",* Energy Economics.

[53] Lesschen, J.P., et al. (2011), *"Greenhouse gas emission profiles of European livestock sectors"*, Animal Feed Science and Technology, 166-167, 16-28.

foods with a high climate footprint is taken into account. The GreenREFORM's carbon leakage module uses 2014 data from the GTAP database and carbon leakage coefficients from GTAP-E. In the GreenREFORM calculations, it is the greenhouse gas intensity in the activity types and regions where production increases the most that is important for the carbon leakage and not the greenhouse gas intensity abroad as a whole, in contrast to the partial calculations in steps 1-4. It should be noted that the assumptions about where production will increase the most are subject to some uncertainty, *see Section 3 on foreign trade below.* The calculation assumes that a number of EU countries have restrictions on emissions from the Effort Sharing Regulation sector, while there are no restrictions on emissions for non-EU countries (thus, the Paris Agreement is assumed to be non-binding). It can be seen that if, in relation to step 4b, it is assumed that there are binding restrictions in the Effort Sharing Regulation sector in the EU, the carbon leakage rate is further reduced to 21 per cent.

Carbon leakage rates in primary models

Table 7.17 presents the estimated carbon leakage rates for models 1-3, as presented in *Chapter 2*. The carbon leakage rates are based on steps 3-5, which are described above. The carbon leakage rate gradually decreases from models 1 to 3. This is due to the fact that models with a high share of technological reductions for a given CO_2-eq reduction have a relatively limited change in the occupational structure of the economy and therefore lower structural effects. Therefore, there is a less risk of carbon leakage. The gradually lower carbon leakage rate from models 1 to 3 should be seen in light of the fact that the subsidy for technological reductions from biochar by pyrolysis and other possible technologies increases, and the socio-economic costs rise as a result of that.

Table 7.17. Carbon leakage rates of the models (2030 effects)

	Per cent
Model 1	20.5-44.1
Model 2a	13.0-29.6
Model 2b	8.4-23.1
Model 3a	8.0-20.4
Model 3b	3.5-12.3

Note: Based on steps 3-5, *see Table 7.16*. Changes in foreign emissions are stated in million tonnes of CO_2-eq and rounded to the nearest 10,000 tonnes. Other effects include a tax on F-gases, removal of carbon-rich agricultural land and subsidies for biochar by pyrolysis. A tax on F-gases leads to reductions of 0.1 million tonnes of CO_2-eq in 2030, which is assumed to be 100 per cent structural effects. Tax on F-gases, set-aside of agricultural land and subsidies for pyrolysis lead to reductions of 0.1, 0.3 and 0.2 million tonnes of CO_2-eq in 2030, respectively, which is assumed to be 100 per cent technical and activity effects.
Source: Own calculations

The impact of assumptions on the size of the carbon leakage

As described in the previous section, there are a number of assumptions that have a significant impact on the calculations of the carbon leakage effect. This includes assumptions about 1) the greenhouse gas intensity of Danish agriculture relative to other countries, 2) assumptions about policy response abroad and international reduction targets, and 3) assumptions about global trade patterns.

1. Greenhouse gas intensity in Danish agriculture relative to other countries

As described above, the carbon leakage effect depends, among other things, on Danish agriculture's greenhouse gas intensity relative to the countries to which production will potentially shift after the introduction of a CO_2-eq tax. For example, if Danish agriculture has a lower greenhouse gas intensity than foreign agriculture, this will increase the carbon leakage effect of a CO_2-eq tax, as the production of a given product will have a larger CO_2-eq footprint if it is produced abroad rather than in Denmark.

Conversely, it will reduce the carbon leakage effect of a CO_2-eq tax if foreign countries have a lower greenhouse gas intensity than Danish agriculture. When calculating carbon leakage effects, it is therefore important to consider the emissions, earning capacity and production conditions of farm types in Danish agriculture relative to similar farm types in foreign agriculture.

Within the literature, three studies can be highlighted that shed light on the climate impact of specific countries, including Denmark, *see Box 7.9*.

Box 7.9

Description of three studies that review the climate effectiveness of, among other things, Danish agriculture

Lesschen et al. (2011) finds that Danish agriculture is among the most climate-friendly in the EU, while Weiss & Leip (2012) finds that Danish agriculture is among the least climate-efficient in the EU.[54] A third study by Wirsenius et al. (2020) finds that Danish agriculture, specifically dairy and pig production, is among the most climate-efficient from a global perspective, but that other major exporting countries of e.g. dairy products are also relatively climate-efficient.[55] Thus, the carbon leakage effect for Danish agriculture as a result of a CO_2-eq tax will be reduced if the countries to which production is shifted are as climate-efficient as Denmark, and the carbon leakage effect will increase if the countries are less climate-efficient.

The differences in the results in the three studies can be attributed to different approaches to calculating emissions from land use, changes in land use and forestry (LULUCF). Lesschen et al. (2011) do not include emissions from animal feed production based on land use change, which means that the climate footprint does not take into account whether production takes place on land that has recently been used for non-agricultural purposes. Weiss & Leip (2012), on the other hand, include emissions in production as a result of land use changes, e.g. deforestation of rainforest in South America for soy production, which is not included in Denmark's emissions inventory and thus not in the 70 per cent target. For this reason, their calculation of the carbon footprint of animal production takes into account that land for feed production may have been used for non-agricultural purposes in the past. This climate impact due to land use change abroad leads back to the country's soya imports, which increases the international climate footprint of Danish agriculture. Wirsenius et al. (2020) attempt to account for the opportunity cost of all feed production by including the fact that all agricultural land can, in principle, be converted to e.g. forest. With this calculation method, the climate impact of Danish agricultural production is significantly lower.

The Expert Group assesses that Danish agriculture's relative climate efficiency is associated with significant uncertainty, as it largely depends on how emissions are calculated and which countries that are compared with.[56] Thus, considerations about the relative greenhouse gas intensity of Danish agriculture depend on the extent to which a shift is expected and which countries Danish production may shift to. For example, it depends on whether a shift is to non-EU countries with less climate-efficient agricultural production or to countries that are relatively more climate-efficient.

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[54] Weiss, F. & Leip, A. (2012), *"Greenhouse gas emissions from the EU livestock sector: A life cycle assessment carried out with the CAPRI model"*, Agriculture, Ecosystems and Environment 149, 124-134.

[55] Wirsenius, S., et al. (2020), *"Comparing the Life Cycle Greenhouse Gas Emission of Dairy and Pork Systems across Countries Using Land-Use Carbon Opportunity Costs"*, Working Paper, World Resources Institute.

[56] See e.g. Mogensen, L., et al. (2022), *"Vidensyntese om livscyklus vurderinger og klimaeffektivitet i landbrugsektoren" (Knowledge synthesis on life cycle assessments and climate efficiency in the agricultural sector)*, Aarhus University, DCA Report No. 200, February 2022.

2. Climate policy abroad and international objectives
The carbon leakage effects of a CO_2-eq tax on Danish agriculture will largely depend on foreign climate policy and the credibility of compliance with non-binding international agreements, such as the Paris Agreement. It should be noted that agricultural emissions are regulated through the EU's Effort Sharing Regulation, and if other EU countries' agricultural production increases as a result of a Danish CO_2-eq tax, it will immediately put pressure on these EU countries to reduce emissions in other sectors covered by the Effort Sharing Regulation, such as road transport.

It is expected that the EU climate policy will have an impact on carbon leakage and that European and global climate action will reduce carbon leakage. The size of the calculated carbon leakage effects will be different if other assumptions are made about foreign climate policy and the credibility of compliance with non-binding international agreements, such as the Paris Agreement.[57]

The EU's upward revision of the 2030 target of a reduction in CO_2-eq emissions of at least 55 per cent, together with the EU's Carbon Border Adjustment Mechanism (CBAM), may thus have an impact on carbon leakage. However, agricultural products are currently not covered by CBAM. Binding climate policy in the EU can reduce the displacement of the part of Danish production assumed to be taken over by Denmark's trading partners in the EU and thus reduce the extent of carbon leakage, *see below on foreign trade.*

3. Foreign trade
Carbon leakage through foreign trade are calculated by, for example, a reduction in Danish production in a given industry, giving rise to a corresponding increase in output in each of the other regions based on a trade-weighted average, i.e. depending on the initial trade with Denmark in the industry in question in each region.

Even if initial trade patterns are expected to follow to some extent the current differences in production and transport costs, product quality, etc., across regions, it is not certain that changes in Danish production will lead to proportional changes in foreign output according to current trade patterns. For example, production could be taken over to a greater extent by one of the other regions, or simply distributed among the regions in a different way than the initial Danish trade pattern suggests.

There can be a wide range of factors that affect international trade patterns over time, including climate policy abroad, technology development, trade agreements, etc. As it can be difficult to predict changes in future trade patterns, the more general assumption presented above is used.

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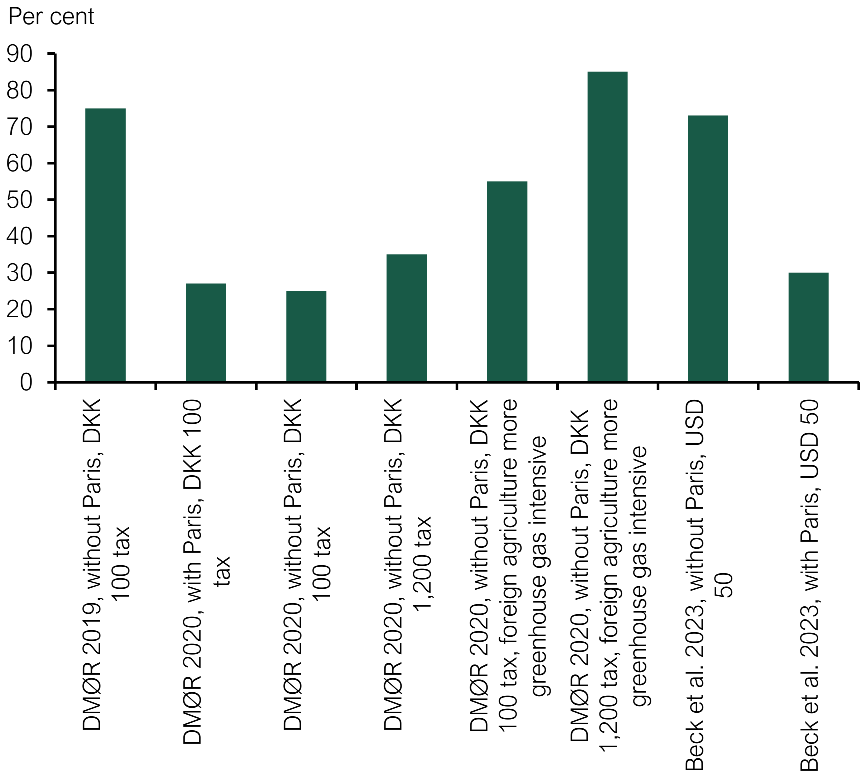
[57] See e.g. Kraka: "Landbrugets lækage afhænger kritisk af udlandets klimapolitik" (Agriculture's carbon leakage depends critically on foreign climate policy), 31 May 2023, (https://kraka.dk/analyse/landbrugets_laekage_afhaenger_kritisk_af_udlandets_klimapolitik)

Studies of carbon leakage

Three studies, namely the 2019 report from the Danish Environmental Economic Council[58], the 2020 report from the Danish Environmental Economic Council[59] and Beck et al. (2023), estimate the carbon leakage effects of a CO_2-eq tax in Denmark. Carbon leakage rates are calculated both in aggregate and by industry. The variation in carbon leakage rates in agriculture can be seen in *Figure 7.2.* The carbon leakage estimates in the studies vary between 21-85 per cent depending on the model approach, assumptions about relative greenhouse gas intensity in agriculture and assumptions about climate policy abroad. It should be noted that the 2019 report from the Danish Environmental Economic Council (DMØR) and Beck et al (2023) do not include technical reduction options in the main scenarios. The reasons for the large variation in the results of the carbon leakage rate are discussed in *Box 7.10*.

Figure 7.2. Studies of carbon leakage rates for agriculture



Source: DMØR (2019), DMØR (2020) and Beck et al. (2023)

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[58] Secretariat of the Danish Environmental Economic Council (2019), *"Economy and Environment 2019*", Report from the Presidency.

[59] Secretariat of the Danish Environmental Economic Council (2020), *"Economy and Environment 2020*", Report from the Presidency.

Box 7.10

Review of three studies that estimate the carbon leakage effects of a CO_2-eq tax for Denmark

The 2019 report from the Danish Environmental Economic Council (DMØR) is based on a modified version of the GTAP-E model. A 2019 report from the Danish Environmental Economic Council (DMØR) found a total carbon leakage rate for Denmark of 45-53 per cent and a separate carbon leakage rate for agriculture of 75 per cent in the baseline scenario. Here, the baseline scenario represents a situation where 1) a number of EU countries have restrictions on emissions from non-ETS sectors, 2) there is no restriction on emissions for non-EU countries and 3) Danish climate policy only reduces the amount of allowances in the EU ETS to a limited extent in the long term. These assumptions are adjusted in the five alternative scenarios, resulting in a range in carbon leakage rates of 27-75 per cent for agriculture.

In a 2020 report from the Danish Environmental Economic Council (DMØR), it was concluded that the total carbon leakage rate for the Danish economy is 21 per cent in the central scenario where the GTAP-E model is coupled with the REFORM model. The large differences in carbon leakage rates between the two reports are due to the different assumptions made in the report. The Danish Environmental Economic Council points out that the primary reasons for the lower carbon leakage for the Danish economy in the 2020 report are that:

- A smaller share of CO_2-eq reductions take place in the EU ETS sector, from 64 per cent in the 2019 report to 19 per cent in the 2020 report, lowering the overall carbon leakage rate.
- The carbon leakage rate is assumed lower within the EU ETS, where an EU ETS leakage rate of 83 per cent was used in the 2019 report compared to 20 per cent in the 2020 report. The reason for this can be found in the time horizon for the reduction of the Danish demand for allowances, which in the 2019 report went to 2060, but in the 2020 report it only goes to 2030.
- The carbon leakage rate in agriculture is lower than in the 2019 report.

A report from Kraka (2023) argues that the carbon leakage rates found for agriculture are underestimated in the 2020 report from the Danish Environmental Economic Council (DMØR).[60] Kraka points out, among other things, that the model used in the 2020 report does not include capital mobility between Denmark and abroad, which would increase the carbon leakage rate, as the introduction of a CO_2-eq tax will lead to falling productivity in Danish agriculture and thus the relocation of capital, which increases foreign emissions. In addition, Kraka points out that the modified REFORM model used in the 2020 report from the Danish Environmental Economic Council (DMØR) does not include adjustments in the land values, which results in too high an adjustment in crop production and thus leads to a lower leakage rate. It is thus the assessment of Kraka (2023) that the carbon leakage rate for agriculture is higher than estimated in the 2020 report from the Danish Environmental Economic Council (DMØR).

In Beck et al. (2023), the GTAP-E model is used in a modified version in line with the modelling approach in the 2019 report from the Danish Environmental Economic Council (DMØR). A carbon leakage rate of 73 per cent in agriculture is estimated at a CO_2-eq tax of just over DKK 300 per tonne if it is assumed that the Paris Agreement is not binding, and 30 per cent if the Paris Agreement is binding, *see Figure 7.2*. However, the study does not include technical conversion, which may mean that the study overestimates the carbon leakage rate. The study shows that there is a large variation in agriculture's carbon leakage rates within the model due to assumptions about international climate policy.

The large differences in the estimates of carbon leakage effects thus result from the different underlying assumptions and modelling assumptions, especially regarding the greenhouse gas intensity of Danish agriculture relative to other countries, current and future climate policies abroad, as well as the model and database used and their level of detail.

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[60] Ulrik Beck, Andreas Lund Jørgensen, Peter Kjær Kruse-Andersen and Emma Terreni. (2023): *"Lækageraten i dansk landbrug" (The carbon leakage rate in Danish agriculture).* Kraka on 31 May 2023, (https://kraka.dk/analyse/landbrugets_laekage_afhaenger_kritisk_af_udlandets_klimapolitik).

7.9 Environmental Externalities

The Expert Group's terms of reference state that the second interim report must include an assessment of the advantages and disadvantages of regulatory solutions, including taxes, that address CO_2-eq emissions and other externalities, including environment and health. This section explains the environmental externalities that are included in the calculated shadow prices of CO_2-eq reductions in the Expert Group's regulatory models.

Agriculture's CO_2-eq emissions and other negative externalities are largely linked to the same agricultural activities. This means that environmental regulation generally reduces agriculture's CO_2-eq emissions, just as other negative environmental externalities in agriculture can be reduced by CO_2-eq regulation.

There are a number of environmental externalities associated with land use in agriculture, including groundwater pollution and oxygen depletion in lakes and coastal waters. For example, reducing fertiliser usage will reduce phosphorus discharges to lakes and thereby improve the state of the environment. At the same time, reducing fertiliser usage will reduce nitrogen leaching into the groundwater, thereby improving the quality of drinking water.

A decrease in agricultural production will reduce agricultural nutrient emissions and potentially provide more space for nature. Both parts will benefit biodiversity.

For some externalities, valuation of the reduction is difficult, as quantification of the value requires both a clear connection between land use and effect, and quantification of the value of the effect. Therefore, the value of e.g. reduced phosphorus discharge to lakes and nitrogen leaching to groundwater is not calculated, even though it has a socio-economic value. This is primarily due to a lack of valuation of the damaging effects of phosphorus application and the fact that the mechanisms of land use nitrogen leaching's impact on groundwater have not been determined at this time.

Two environmental externalities are particularly linked to the emission sources that are regulated by climate regulation of agriculture and can be quantified and valued at the same time. These are ammonia emissions and nitrogen leaching, both of which are specifically linked to fertilisers. These two externalities are included in the modelling calculations and are valued based on the socio-economic value of reduction. In addition, the recreational values associated with the recommended afforestation are calculated.

The three quantified values of environmental externalities are adjusted for the increase in total disposable family income up to 2024. This implies an assumption that the value of recreational services follows the development in total income, which means that the income elasticity of the individual family's demand for recreational services is 1 and that demand otherwise develops proportionally to the development in the number of households. The nominal value of recreation is thus adjusted not only for inflation, but also for changes in average real income and population size. Drupp et al. (2023) recommend this practice.[61]

Ammonia

The largest source of Danish ammonia emissions is agriculture. Ammonia emissions come mainly from fertilisers. Climate regulation that affects the amount of fertiliser thus has a direct effect on ammonia emissions, just as certain climate technologies for stables and slurry storage also reduce ammonia emissions, such as covering slurry tanks. The national reduction of ammonia emissions in 2030 as a result of a tax on CO_2-eq emissions in agriculture is estimated with GreenREFORM.[62]

The two main externalities from ammonia emissions are human health effects and increased nutrient loading in natural areas. The nutrient load on natural areas is well known, but the impact is largely geographically dependent on proximity to ammonia-sensitive natural areas, and it is not quantified, so the value cannot be included. This means that only the value of human health effects is included in the modelling calculations. The value of reduced ammonia emissions is thus a lower bound estimate.

The health effects of ammonia emissions from agriculture have been calculated by the DCE (2023)[63] based on dose-response modelling in relation to the impact on the population. The valuation is also carried out by DCE based on the value of statistical life as calculated in the Ministry of Finance's documentation note on the value of statistical life.

Ammonia can be transported long distances in the atmosphere, so there is a high degree of exchange of ammonia between countries. Therefore, only a small proportion of ammonia emitted on Danish soil will have a negative impact in Denmark. Based on Brand et al.'s (2023) calculation, the socio-economic damage value for ammonia from agriculture is set at DKK 43 per kg of ammonia. However, in connection with the valuation for the green tax reform, only the value of damage on Danish territory is used, which corresponds to DKK 10 per kg of ammonia.

The contribution of Danish sources to the total ammonia load on Danish territory is limited. It is therefore considered that the stated reductions are marginal and that the value can be approximated as constant.

Nitrogen discharge to coastal waters

Nationwide, agriculture accounts for almost 70 per cent of nitrogen emissions to coastal waters and is thus the largest source[64] of nitrogen emissions to the aquatic

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[61] Drupp, M., M. Hänsel, E. Fenichel, M. Freeman, C. Gollier, B. Groom, G. Heal, P. Howard, A. Millner, F. Moore, F. Nesje, M. Quaas, S. Smulders, T. Sterner, C. Traeger, F. Venmans (2023). The increasing benefits from scarce ecosystems. Appears in *Science*

[62] Hansen, M.K. and Berg, A.K. (2023). *"Modellering af ammoniakudledninger i landbruget"* (Modelling ammonia emissions in agriculture). DREAM documentation note 2023, December 2023,(**https://dreamgruppen.dk/Media/638387647814477951/modellering_af_ammoniakudledninger_i_landbruget.pdf)**

[63] Brandt, J., Christensen, J.H. and Andersen, M.S. (2023). "Miljøøkonomiske beregningspriser for emissioner 4.0" (Environmental economic calculation prices for emissions 4.0). Aarhus University, DCE, Scientific note no. 2023/54,(N2023_54.pdf (au.dk))

[64] Danish Environmental Protection Agency (2023). *"Udledning af kvælstof til kystvand opdelt på kilder"* (Discharge of nitrogen to coastal waters by source). Note to the Environment and Food Committee (https://www.ft.dk/samling/20222/almdel/MOF/bilag/121/2657955/index.htm)

environment. The main source of nitrogen leaching is nitrogenous fertilisers in the form of livestock and artificial fertilisers. The national reduction in fertiliser application as a result of regulating CO_2-eq emissions in agriculture in 2030 is estimated with GreenREFORM. This has been converted to nitrogen discharge to coastal water by the Danish Environmental Protection Agency according to the following procedure.

The national estimated reduction in fertiliser application is distributed to coastal water catchments proportional to past fertiliser use.[65] This results in a reduction in fertiliser usage for each coastal water catchment. Some of the fertiliser applied is taken up by plants, metabolised or retained before a smaller proportion of the applied nitrogen reaches coastal waters. The assessment takes into account whether commercial fertiliser or livestock manure is applied. As mentioned, some of the nitrogen lost from the field is retained or converted before it reaches coastal waters. This is recognised as a percentage specific to each coastal water catchment. The change in fertiliser application thus gives the change in nitrogen emissions for each individual coastal water body.

The overall goal of the Water Framework Directive is to achieve a good condition in the water environment by the end of 2027 at the latest. With the *Agreement on the Green Transformation of Danish Agriculture* (2021), efforts have been agreed until 2027 that are estimated to ensure the prerequisites for good ecological status, provided that the shortfall in the nitrogen initiative of 2,600 tonnes and any updating of the effort requirement is decided when the agricultural agreement is revisited in 2024. A tax can only be introduced from 2027, and the achievement of the target must be assumed to have been promised at that time. A tax introduced from 2027 will therefore not contribute to the fulfilment of the Water Framework Directive in 2027, but may provide the opportunity to subsequently relax the nitrogen regulation implemented at that time to meet the objectives of the Water Framework Directive. The value of nitrogen reductions will thus be the reduction in costs to achieve such a good condition in the aquatic environment, which varies somewhat across the 108 coastal water catchments in Denmark. The costs of target fulfilment are calculated in a research project commissioned by the Danish Environmental Protection Agency with two models, the SMART model (Jacobsen, 2022)[66] and TargetEconN (Hasler et al., 2022)[67].

The costs calculated with the two models are used to provide a range for the socio-economic value of nitrogen reductions. The costs cover the set-up, running and opportunity costs of implementing agricultural measures. The calculations with the two

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[65] The distribution of commercial fertiliser and livestock manure is calculated in 2017 at ID15 catchment level and described in (Børgesen and Bach (2023). Børgesen, C.D., Bach E.O. (2023). *"Modelberegnet nitratudvaskning fra landbrugsarealet til en vurdering af grundvandspåvirkningen på grundlag af landbrugsdata fra 2017 og klimadata fra 1990-2010"* (Modelled nitrate leaching from agricultural land for an assessment of groundwater impact based on agricultural data from 2017 and climate data from 1990-2010). Aarhus University, DCA Advisory Note.

[66] Jacobsen, B. H., (2022). *"Økonomiske konsekvensberegninger af scenarier for vandområdeplaner 2021-2027 med brug af SMART-modellen"* (Economic impact assessments of scenarios for river basin management plans 2021-2027 using the SMART model). University of Copenhagen, IFRO Commissioned Work No. 2022/03, (https://static-curis.ku.dk/portal/files/320645278/IFRO_Udredning_2022_03.pdf)

[67] Hasler B., Filippelli R., Levin G. & Nainggolan D. (2022). *"Økonomiske konsekvensberegninger for vandrammedirektivet i 2027" (Economic impact calculations for the Water Framework Directive in 2027). Scenarios for the full implementation of VP3 action requirements for coastal water catchments 2021-2027".* Aarhus University, DCE Scientific Report No. 502, (http://dce2.au.dk/pub/SR502.pdf7)

models have been carried out in the same time period, and we have endeavoured to ensure that the data basis for the two models is as similar as possible.

TargetEconN models the cost-effective distribution of instruments at field level in the coastal water catchment, while the SMART model does not optimise the placement of instruments within the catchment area. TargetEconN, therefore, selects fields for implementation where the contribution margins are low, while SMART uses more average costs. The results of both models assume optimal use and placement of instruments, which is not expected to be achieved in practice through regulation. The real costs of target fulfilment and thus the estimated value of reducing nitrogen emissions will therefore be higher.

The value of nitrogen reduction for each coastal water catchment is calculated based on the cost of the marginal instrument that must be used to fulfil the nitrogen target, as this reflects society's willingness to pay for nitrogen reduction in the coastal water catchment in question. This will be accurate for smaller reductions, but for larger reductions, this will be an overestimate.

The valuation of nitrogen is based on the fulfilment of politically set targets[68], which are translated into different levels of reduction targets across coastal water bodies. Due to increasing marginal costs for the majority of the instruments that can be used in nitrogen regulation, the socio-economic value of nitrogen reductions will vary across areas. In coastal water catchments without a need for action, further nitrogen reductions are not valued, as the valuation is tied to target fulfilment. If further improvement of the environmental status in coastal water catchments that have achieved good ecological status has a socio-economic value, this would mean that the valuation is an underestimate.

On this basis, the socio-economic value of nitrogen reduction is estimated to be from DKK 0 per kg nitrogen to between approx. DKK 380 and 600 per kg nitrogen, depending on the calculation model and coastal water catchment where the reduction takes place. Based on the calculated reduction in nitrogen emissions for each coastal water catchment, the full value is calculated, first per coastal water catchment, then totalled to the national level. This results in two estimates of the value of this side effect of the regulation, and the average is represented in the model section.

Set-aside of land for forestry or peatland will also reduce nitrogen emissions. Partly because of the reduced fertiliser consumption associated with the set-aside, and partly because the areas will act as "filters" that reduce nitrogen leaching into the aquatic environment. The value of this effect on Water Framework Directive target fulfilment will depend on where the area is set aside. Using the above estimates of marginal costs from Jacobsen (2022) and Hasler et al. (2022), the average value would be approx. DKK 102 per kg.

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[68] The Agreement on the Green Transformation of Danish Agriculture initiates nitrogen-reducing measures corresponding to a reduction in emissions to coastal waters of approx. 10,400 tonnes of nitrogen. When revisiting the agreement, a decision is made on how to handle the reduction deficit of approx. 2,600 tonnes of nitrogen. An evaluation of the technical and legal basis for the nitrogen initiative is currently being carried out ("second opinion"). This can, among other things, lead to an adjustment of the need for a nitrogen initiative.

Recreational values

Afforestation has a recreational value. Recreation valuation is methodologically well-established in Denmark, where the population's use of forests has been studied extensively since the 1970s, when the first major national study was launched. The Danish Economic Councils (2014) analysed the Danish population's use of Danish nature in order to evaluate state and private afforestation.[69] The valuation is based on a multi-site travel cost method where Danes' observed use of natural areas and thus willingness to incur transport costs is used to derive the value of recreation.

Recreational values of new areas vary significantly across geography, with population density and the number of alternative recreational areas significantly impacting the value of a new area. It is not possible to take geographical aspects etc. into account in the valuation of the recommended afforestation, as the recommendations do not include a geographical element. Therefore, an average value is used.

The valuation of DKK 4,038 per hectare (The Danish Economic Councils, 2014) should be seen as an average valuation for privately owned forests. State forests are typically located in more densely populated areas and have better access and facilities. Location, layout, size and access conditions affect the use of the forest and thus the recreational value. The recreational value of state forests is estimated to be around DKK 50,000 per hectare (The Danish Economic Councils, 2014), which is significantly higher than the value of private forests.

Based on these analyses, it is not possible to assess the impact of forest age and species composition on the recreational value.

Socio-economic value of side effects in the models

Table 7.18 shows shadow prices for the models with and without the value of reducing the described externalities (side effects).

Table 7.18. Shadow price for the presented models excluding and including side effects (DKK per tonne of CO_2-eq)

	Shadow price excluding side effects	Shadow price side effects
Model 1	475	150
Model 2a	525	250
Model 2b	550	325
Model 3a	750	475
Model 3b	775	575

Source: Own calculations.

Table 7.19 presents the socio-economic value in the individual models for each of the calculated externalities in 2030.

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[69] The Danish Economic Councils (2014) *"Værdi af rekreative områder"* (Value of recreational areas), in: Economy and Environment 2014. Copenhagen, pp. 103–192, (https://dors.dk/files/media/rapporter/2014/m14/m14_kapitel_4.pdf*)*

Table 7.19. Socio-economic value of environmental effects (DKK million in 2030)

	Nitrogen	Ammonia	Recreation	Total
Model 1	480	100	200	770
Model 2a	380	60	200	630
Model 2b	200	40	200	430
Model 3a	260	40	200	490
Model 3b	170	20	200	380

Note: Totals may not add up due to rounding
Source: Own calculations.

7.10 Food Security and Calorie Production

This appendix analyses the impact of a tax on agricultural activities on food security and food production for human consumption in Denmark. A CO_2-eq tax in isolation is not expected to reduce food security in Denmark. In addition, the analysis shows, with great uncertainty and under certain assumptions and conditions, that a tax of DKK 750 per tonne of CO_2-eq is estimated to lead to a decrease in Danish food production for human consumption of 2-4 per cent, corresponding to a total loss of 225-500 bn calories (kcal). The very limited decrease in food production for human consumption, despite the large decline in animal production, is due to an expected shift in activity from feed production to other crop production.

7.10.1 Food security in the EU

Food security is about ensuring a sufficient supply of food for each individual or region (e.g. the EU). With a growing world population and changes in dietary habits, there is a corresponding need to increase global food production. In addition, some major countries, such as China and Brazil, are moving towards increased consumption of animal products, partly due to a growing middle class. The OECD and the UN Food and Agriculture Organisation (FAO) expect global demand for animal proteins to increase over the next 10 years.[70]

Basically, animal production is more land-intensive than crop production. This is partly because livestock production requires additional land use for feed production. Thus, there is generally a higher need for inputs in the production of animal foods compared to plant-based foods. The balance between animal and plant-based food consumption thus determines how much land use is needed and how many calories are produced for human consumption.

The EU's food trade balance

In 2020, the EU's net exports of food and agricultural products totalled EUR 62 bn, driven mainly by processed foods. Thus, the EU primarily imports cheap raw materials, such as soybeans for animal feed and cocoa, and exports processed foods, such as chocolate and dairy products.

A report from the European Commission in 2021[71] states that more than 85 per cent of EU food and agricultural production is consumed within the EU, but that the share of exports to countries outside the EU has been increasing. The Commission also emphasises that the EU has experienced high income growth by exporting certain food products (e.g. wine, cheese and pork) to third countries, whose consumption patterns have changed with rising levels of prosperity.

The EU is also the world's largest exporter of food and agricultural products and in 2019 was the world's third largest importer after the US and China. Today, approx. 6-10 per cent of food and agricultural products are imported into the EU, of which imports of fishery products account for 24 per cent.

The self-sufficiency of food in the EU

[70] OECD-FAO Agricultural Outlook 2023-2032.

[71] EU Commission, *"Contingency plan for ensuring food supply and food security in times of crisis"*, 2021.

The European Commission also calculates a self-sufficiency rate, which acts as an indicator of how much of specific products are imported from outside the EU. From 2017-2021, the EU was self-sufficient in a wide range of food products, including wheat, animal products, fruit and vegetables. In contrast, the EU was not self-sufficient when it came to certain cereals (e.g. rice and maize), oilseeds (e.g. rapeseed oil and soybeans), protein crops (e.g. lentils), and certain fruits and vegetables. In addition, the EU's self-sufficiency rate for fisheries products was only 42.5 per cent and only 14 per cent for the five most consumed types of fish (e.g. tuna, salmon, cod, etc.).

These trade deficits for specific commodities can be interpreted as indicating that the food system in the EU may be exposed to a certain degree, as it may be difficult to substitute certain imported commodities in the short term, as they are widely used in the production of other food products. For example, price increases for oilseed can translate into higher production costs for animal products, which can lower production. However, the report from the European Commission emphasises that it would require a number of significant effects to occur at the same time to challenge the food security in the EU. This could, for instance, be by having a high import dependency from specific countries coupled with further disruptions in supply chains elsewhere in the EU.

The EU is thus a significant global market for the production, trade and consumption of food. It is estimated that the EU is self-sufficient in a number of important food categories, but that the EU's significant trade surplus is primarily due to exports of processed foods, which is why there is also some dependence on imports of certain raw materials from third countries. However, it is estimated that food supply in the EU will only be challenged if several special circumstances occur at the same time. It is also pointed out that within certain food categories, there could be some form of substitution in emergency cases. In addition, it will depend on how dietary habits change in the future, especially as a result of changing climate policies and regulations, the introduction of CO_2-eq taxes and increasing climate concerns, all of which can lead to behavioural changes in the population.

7.10.2 Food safety and security of supply in Denmark

Denmark has a high degree of self-sufficiency in cereals, oilseeds, dairy products and general animal production. However, in 2021, self-sufficiency rates were only 83 per cent for beef, but for a wide range of products, Denmark was a net exporter and had a self-sufficiency rate above 100 per cent. For example, Denmark had a self-sufficiency rate of 333 per cent for pork, 232 per cent for general meat production, 156 per cent for dairy products and 112 per cent for cereals. However, there is an estimated self-sufficiency rate of 0 for soybeans, for example, which is why Danish farmers primarily trade with countries outside the EU to meet demand. Soybeans, are for example used as protein in animal feed, where there is limited scope for producing alternative crops in Denmark that can be used for animal feed, such as broad beans. As part of the Agricultural Agreement from 2021, the parties agreed to transition to more plant production and a larger national protein supply, which are key elements in the green transition.

The effect of a tax

The introduction of a CO_2-eq tax on agriculture can have various effects on food production in Denmark. Animal production may experience a decline, which is estimated to lead to a decline in both livestock and feed production. A possible consequence of this could be a weakened food security for animal products in Denmark.

However, these production decreases, e.g. in the number of dairy cattle, can potentially also release areas that can be used for other crop production instead of feed production.

There may thus be some contradictory effects of a CO_2-eq tax on food security in the form of reduced animal production and increased crop production. However, an isolated tax on Danish agriculture alone cannot be expected to have a significant impact on European food production.[72]

In addition, Denmark is largely self-sufficient when it comes to several food products. Thus, it is not expected that a CO_2-eq tax in isolation will significantly reduce the food security in Denmark.

7.10.3 Calorie production for human consumption in Danish agriculture

Crop production in Denmark is characterised by delivering a high degree of input to animal production in Denmark. There are no precise calculations of how much of the Danish agricultural area is used for feed production. The University of Copenhagen estimates that approx. 65 per cent of Danish agricultural area was used for feed production in 2022.[73] In addition, a large part of Danish feed consumption is imported. According to the University of Copenhagen, Denmark is 69 per cent self-sufficient in protein for animal feed, with the rest being imported.[74]

Feed production thus indirectly contributes to the total calorie production in Denmark, as it is used as an input in livestock production. In the use of feed for livestock production, there is an energy loss as the energy content of the feed is reduced in the conversion to the final output, i.e. meat and dairy products. In addition to livestock production, the total calorie production in Danish agriculture is also made up of the crop production of food for human consumption.

As the global population increases, it is expected that the global demand for food will also increase. The OECD and FAO estimate that there will be an increase in global food consumption of 1.4 per cent per year over the next 10 years.[75] In this context, it can be assumed that if fewer calories are produced in Denmark for global sales, the increased global demand will have to be met elsewhere. However, to the extent that a CO_2-eq tax reduces Danish feed imports, it may also free up foreign feed production for other uses.

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[72] In 2020, Danish agriculture was the seventh largest producer in the EU and accounted for approx. 2-3 per cent of the total output from the EU countries' agricultural sectors, see European Commission, "*Statistical Factsheet - European Union*", June 2021.

[73] Analysis of barriers and possible regulatory instruments to promote increased Danish production of green protein sources for food and feed, IFRO Commissioned Work 2023_20.

[74] Green protein sources for animal feed, IFRO Commissioned Work 2023_07.

[75] OECD-FAO Agricultural Outlook 2022-2031.

Structural effects as a result of a CO_2-eq tax for animal production, in the form of production decline or relocation, can also lead to a decline in feed production. In isolation, lower livestock production will reduce the total calorie production in Denmark. However, a decline in animal production also releases land from feed production, which can be used to produce plant-based food, for example.

If it is assumed that the vacant areas can be taken over by plant production for human consumption, such as cereals or legumes, the accompanying increase in calorie production can reduce the initial decrease in total calorie production due to the decline in animal production.

However, plant-based products don't always contain as many vitamins and minerals as animal-based products. For example, grains lack certain amino acids and micronutrients (vitamins and minerals - e.g. calcium, iron and vitamin B). Livestock, on the other hand, are good at converting energy-dense, but micronutrient-poor grains from their feed into more nutrient-dense protein sources. Therefore, grains from feed production cannot be used as like-for-like for human consumption, as other plant-based foods, such as legumes, may also be needed to achieve a suitable mix of amino acids in the dietary composition. There may, therefore, be a need for a shift in crop production from the current land use.

Change in calorie production in structural equilibrium

Table 7.20 shows estimates of changes in calorie production (range) based on the model calculations for a CO_2-eq tax of DKK 750 per tonne on emissions from both fertiliser usage and livestock.

The results show that a tax is estimated to lead to a decrease in Danish food production for human consumption of 2-4 per cent, corresponding to a total loss of 225-500 bn kcal, *see Table 7.20.* In isolation, animal calorie production for human consumption is estimated to decrease by approx. 1,425 bn kcal, although this is offset by an increase in crop production of approx. 925-1,200 bn kcal, depending on how large a share of crop production is produced for human consumption. It is estimated that the total calorie production for human consumption, after the introduction of a tax, will be approx. 12,350-12,625 bn kcal.

In comparison, the average actual calorie consumption for Danes is estimated to be approx. 3,400 kcal per day per person, indicating that the current calorie production can feed approx. 10.4 million people with an average Danish calorie consumption. With a recommended intake of around 2,300 kcal per person per day, the current production level is estimated to be able to feed around 15.3 million people. After the introduction of a tax, the total Danish calorie production is estimated to be able to feed approx. 10.0-10.2 million people with an average actual Danish calorie consumption or alternatively 14.7-15.0 million people with the recommended calorie consumption.

It is assumed that 70 per cent of plant production in Denmark is used for feed production, 15-20 per cent for the production of plant-based food for human consumption, and the remaining 10-15 per cent is used for other purposes, such as rapeseed for biodiesel, Christmas trees, industrial potatoes, flowers or uncultivated land. This assumption regarding the distribution of plant production in Denmark for feed production, human consumption or other uses has a major impact on the results. For example, if 20 per cent of plant production is used for human consumption instead of 15 per cent, the increase in calorie production is reduced by 6 per cent. It should be noted that in the Expert Group's calculations, land will also be taken out of production as a result of the tax making certain land unproductive[76], which also affects the total calorie production in a downward direction.

To account for these differences, a range of the possible effects on the net calorie production for human consumption is shown, depending on assumptions about the distribution of plant production used for human consumption. The figures are subject to significant uncertainty.

Table 7.20. Calculation of the impact of a tax of DKK 750 per tonne of CO_2-eq on calorie production

Production	Calorie production before tax	Calorie production after tax	Change in calorie production SFA tax	Change in production SFA tax
		bn kcal	*per cent*	
Cattle	125	100	-25	-20
Pigs	4,825	3,950	-875	-18
Dairy	3,275	2,750	-525	-16
Animal production (total)	8,225	6,800	-1,425	-17
Plant production (total)				-8
Of which for human consumption	*4,625*	*5,550-5,825*	*925-1,200*	*20-26*
Of which for feed production				*-15*
Total, human consumption	12,850	12,350-12,625	-500; -225	-4; -2

Note: Rounded to the nearest 25 bn kcal. Conventional and organic production have been merged. The ranges indicate the results based on different assumptions regarding the share of crop production for human consumption (15 or 20 per cent)
Source: Own calculations based on figures for production decline in the model calculations and calorie production from FAO, FBS (2020)

In the model calculations, feed imports are estimated to decrease by 14 per cent, corresponding to approx. 775 bn kcal. A degree of so-called calorie leakage must be expected, as some foreign feed production is no longer exported to Denmark, but is instead released for other uses, e.g. feed production for other/own countries, increased plant production for human consumption etc. If it is the case that the reduced feed imports of approx. 775 bn kcal are used abroad in the production of, for example, plant-based production for human consumption, the total calorie production for human consumption will increase by approx. 2-4 per cent.

It should be noted that the above figures are subject to significant uncertainty, including the extent to which it is possible to switch between different types of crops.

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[76] According to the model calculations, a uniform tax on agriculture of DKK 750 per tonne of CO_2-eq means that approx. 9 per cent of agricultural land will be taken out of use by 2030.

7.11 Base Deduction

Model 2 and 3 incorporates a base deduction per animal differentiated by animal type so that the base deduction is on average 50 per cent of the immediate tax payment for a given farm. Thus, the effective tax rate averages approx. DKK 375 per tonne of CO_2-eq in model 2 and approx. DKK 125 per tonne of CO_2-eq in model 3. The base deduction is organised according to the same criteria as for the tax, i.e. with variations based on weight, breed, type of housing, etc.

The combination of a higher marginal tax rate and base deduction in model 2 incentivises the farmer to use technological solutions (e.g. more climate-friendly barns, feed additives) that reduce the tax. The Expert Group estimates that a model with DKK 750 per tonne of CO_2-eq on the margin and a base deduction that on average corresponds to 50 per cent of the immediate tax payment has better properties than a simple reduction of the tax rate to DKK 375 per tonne of CO_2-eq as in the industry's EU ETS.

Table 7.21 shows the CO_2-eq impact, including structural reductions, and the burden on the farmer in models with a base deduction and a simple rate reduction to DKK 375 per tonne of CO_2-eq emitted. The effects show that in the model with a base deduction per animal, the CO_2-eq reduction is 0.3 million tonnes higher, *while* the structural effects are 0.2 million tonnes lower compared to a simple rate reduction. This is because the higher marginal tax rate with a base deduction provides a greater incentive to switch to less CO_2-eq-intensive production, such as changing animal breeds etc. In addition, the burden on the agricultural sector is DKK 75 million lower in the model with a base deduction. The model with a base deduction thus increases the total CO_2-eq reductions and at the same time reduces the overall burden on the agricultural sector as well as the structural effect.

The cost of the model with a base deduction is a higher shadow price compared to a model with a simple rate reduction. This is because the tax model with a simple rate reduction involves larger structural effects that are cheap in socio-economic terms, whereas a tax model with a base deduction involves more expensive reductions from shifts in production, e.g. towards other animal breeds.

Fewer structural effects and a lower burden, on the other hand, reduce the risk of carbon leakage and preserve more of the existing occupational structure. At the same time, the shadow price of the additional reductions remains relatively low compared to other reduction initiatives. Against this background, the Expert Group favours a model with a base deduction over models with a simple rate reduction.

Table 7.21. Effects of base deductions

	CO_2-eq tax of DKK 750 per tonne with a base deduction of 50 per cent	**CO_2-eq tax of DKK 375 per tonne**
CO_2-eq reductions (million tonnes)	2.2	1.9
- of which are structural (million tonnes)	1.0	1.2
Burden on the agricultural sector after adjustment (DKK million)	1,350	1,425
Shadow price incl. side effects (DKK per tonne CO_2-eq)	300	225
Value of side effects (DKK million)	350	350

Note: The shadow price is rounded to the nearest DKK 25. The tax calculation is for the tax on livestock and fertiliser. The value of side effects covers reductions in ammonia and nitrogen emissions. Burden on the agricultural sector after adjustment covers the tax revenue minus the share of the tax that is passed on in higher consumer prices. In the calculations for the CO_2-eq tax of DKK 375 per tonne, it is assumed that there are requirements for feed additives and tent covering with floating layers.
Source: Own calculations.

7.12 Subsidy Scheme for Capacity Reduction in Animal Production

This section examines the possibilities for establishing a voluntary subsidy scheme for full or partial capacity closure of livestock production in order to support structural changes in agriculture.

It is considered immediately possible to obtain EU approval for a voluntary decommissioning scheme for capacity closure based on, for example, environmental or climate considerations. Such schemes have been state aid approved in Belgium and the Netherlands with compensation rates up to 120 per cent. The scheme could target cattle production and be designed with a number of prioritisation criteria that govern the allocation of subsidy, so that, for example, climate considerations or geographical location with associated need for a nitrogen initiative or proximity to Natura 2000 areas are used as a basis for prioritising beneficiaries. It must be determined whether climate considerations can include, for example, that the scheme targets types of housing with high emissions factors in relation to fertiliser management.

The scheme can be organised so that the capacity closure only concerns the keeping of livestock on a property, allowing other agricultural operations, such as plant cultivation or conversion to forestry, to continue. In general, this entails that the associated areas are not included in the scheme. This is linked to the subsidy schemes and the recommendations for increased afforestation and rewetting of peatland areas, as you do not want competition with the other subsidy schemes for the same areas and cause a smaller drain on these schemes. The state aid rules do not preclude the areas from being included, e.g. if synergies to the nitrogen initiative or nature can speak in favour of this.

The scheme cannot include companies that were in crisis at the time the subsidy was granted, *see Box 7.11*. There is no overview of how many cattle farms will be classified as crisis-hit.

At the same time, the subsidy scheme for capacity closure cannot be directly conditioned on the applicant being significantly negatively affected by a future CO_2-eq tax. If there is no such linkage, it is assessed that it is possible to establish a subsidy scheme for capacity closure in parallel with the adoption of a CO_2-eq tax to ensure the achievement of Denmark's climate objectives.

Box 7.11

Definition of a company in crisis

A company in crisis means a company which, without government intervention, will almost certainly have to cease its activity in the short or medium term. Therefore, a company is considered to be in crisis if at least one of the following circumstances occurs:

1) For limited liability companies, when more than half of its subscribed share capital has disappeared as a result of accumulated losses.

2) For companies where at least some of the shareholders have unlimited liability for the company's debts when more than half of the share capital recognised in the company's accounts has disappeared due to accumulated losses.

3) When the company is in bankruptcy proceedings or fulfils the criteria under national rules for bankruptcy proceedings at the request of its creditors.

4) When the company is not an SME and in the last two years has had and still has a debt ratio, i.e. a ratio of book debt to equity, of more than 7.5 and an EBITDA interest coverage ratio of less than 1.0

The support under the scheme can be granted as compensation for the value of the assets measured on the basis of e.g. standardised rates based on the age of the plant etc. In addition, compensation may be granted for the costs of destroying production capacity etc.

A legally binding commitment must be obtained from the beneficiary that the closure of the production capacity concerned is definitive and irrevocable and that the beneficiary will not restart the same activity elsewhere. These commitments must also be binding on any future purchaser of the land or facility in question. This can be secured, for example, by registering a declaration on the property in question.

It is difficult to estimate the overall process time for the dialogue with the European Commission. On average, the Danish Agricultural Agency's experience is that the approval process takes about 8-12 months, but up to 2 years should be expected for the implementation of the necessary national regulatory framework. It will be possible to run the legislative and state aid process in parallel.

It should be noted that in 2023, the European Commission approved a Dutch and a Belgian scheme that provides compensation for the purchase and closure of livestock farms, *see Box 7.12*. However, the approved schemes differ in some areas from the proposed scheme, particularly in that they have the reduction of nitrogen emissions as their primary objective. The schemes are justified on environmental grounds.

Box 7.12

Dutch scheme to decommission livestock farms with high nitrogen emissions

On 3 July, the Dutch government opened a nationally funded scheme for the voluntary closure of livestock farms with high nitrogen emissions. Here, a subsidy is granted for the definitive and irreversible closure of livestock production on the condition that the same activity is not resumed elsewhere. Farmers in the vicinity of Natura 2000 areas (so-called "peak emitters") can be reimbursed 120 per cent of the value of the production capacity (livestock housing, feed silos, etc.), which is calculated based on a standard price per square metre, depending on the type of animal and the age of the facility. In addition, 100 per cent compensation is given for the market value of production rights and destruction costs.

Farmers keep their land and are allowed to use it for crop production. The government has allocated EUR 975 million to the peak emitters scheme, which covers around 3,000 farmers. On 2 May, the European Commission approved the scheme, which runs until 2028. By January 2024, more than 1,250 farms had voluntarily applied to join the scheme.[77]

If the scheme is approved in mid-2024, it is expected to open in mid-2026. The duration of the subsidy scheme can be considered limited to, for example, 12 months for the collection of applications for participation and another 12 months for the actual decommissioning to ensure that the capacity closure scheme can quickly have an impact on the market. Combined with an approach where the subsidy is based on standardised rates, such an arrangement is estimated to increase the likelihood that the EU Commission will approve the subsidy scheme.

Example of possible capacity closure of cattle production

It is proposed that the aid in the scheme for capacity closure should be determined based on the standard rates. This would ensure that the scheme is based on clear, transparent rules that are easy to administer and contribute to the fact that payment will be made significantly faster.

This model shows a stylised example of a capacity closure subsidy scheme that includes the following subsidy measures where 100 per cent compensation is given:

1) Support for the dismantling of existing production capacity of cattle stables.
2) Support for the dismantling of existing production capacity of cattle.
3) Support for the dismantling of existing production capacity of cattle-related equipment.

The subsidy for closing down stables, cattle and cattle-related equipment can be calculated by applying a standard rate per yearling cow, e.g. DKK 20,000 or DKK 25,000. These rates are determined by totalling the asset value of barns, cattle and cattle-related equipment and then dividing by the number of yearling cows on the farms. At subsidy rates of up to DKK 20,000 and DKK 25,000 per yearling cow, respectively, it is estimated with great uncertainty that the farms that will choose to participate in the abandonment scheme possess cattle-related assets with a value corresponding to 15 per cent and 30 per cent of the value of cattle-related assets across all farms, respectively. 15 per cent and 30 per cent of the value of cattle-related assets across all farms.

The cattle farms that are expected to participate in the scheme are typically smaller farms and have approx. 10 per cent or 23 per cent of all yearling cows and heifers in Denmark.

The calculated standard rates do not include the opportunity value of yearling cows and heifers. The slaughter price for yearling cows and heifers is currently not deducted, which could be deducted from the standard rate to get a more accurate calculation of the real value loss.

Table 7.22. Technical calculation of subsidy scheme for capacity closure

	15 per cent of the cattle farms' cattle-related assets	30 per cent of cattle farms' cattle-related assets
Subsidy per yearling cow	DKK 20,000	DKK 25,000
Number of yearling cows culled[1]	52,000 units.	120,000 units.
Cost of subsidy scheme	DKK 1.1 bn	DKK 2.9 bn

Note: There is considerable uncertainty in the estimate. The estimate is based on the total book values of livestock-related inventory, cattle and estimated value of livestock housing in cattle farms in 2021. It is assumed that the subsidy rate corresponds exactly to 100 per cent of the book value of the assets. Destruction costs and administrative costs are not taken into account in the subsidy scheme. 1) The heifers are also included in the closure, which is recognised in the subsidy amount. 2) Covers stables, cattle and cattle-related inventory.
Source: Own calculations based on accounting data from SEGES.

It should be noted that this example is for illustration purposes only. The final design, costs and climate impact of a subsidy scheme for capacity reduction requires a more concrete assessment. Further work is needed to define exactly what specific elements the subsidy scheme should include.

7.13 Distribution and Employment

The terms of reference state that the Expert Group should analyse the economic consequences associated with the models, including the effects on employment, as well as the effects on social balance, including income distribution. This section describes the effects on distribution and employment of introducing CO_2-eq taxes, base deductions and possible requirements for technology use corresponding to the Expert Group's models.

Effects on distribution

The effect of the models on income distribution can be analysed by examining the impact of changes in consumer prices and changes in wages and transfer incomes as a result of the tax. *Table 7.23* presents the average tax burden from changing consumer prices and changing wages and transfer incomes as a percentage of disposable income across income deciles. The results show that the tax burden as a share of disposable income is approximately equally distributed across income deciles, which means that the effect on Gini is estimated to be 0. It should be noted that the calculations do not take into account any derived effects on savings.

The above results should be seen in light of the following effects:

- **The direct price effects** on milk, meat, etc. when the tax is passed on in higher sales prices hit low-income groups a little harder. This is because low-income groups spend a higher proportion of their total consumption on taxed food compared to high-income groups.

- **Indirect price effects** are where the prices of other goods and services fall as part of the tax is passed on in lower wages, reducing production costs in the rest of the economy. This benefits low-income groups relatively more, as they spend a larger proportion of their total consumption on other goods and services compared to high-income groups. As other goods and services make up the vast majority of household consumption, the effect from indirect price effects will dominate over the effect from direct price effects.

- **Wage and transfer effects** cover the fact that part of the tax is passed on to lower wages and that lower wages are reflected in the rate adjustment, which in turn leads to lower transfers. Since high-income households have a larger share of wage income as disposable income (e.g. low-income groups receive more income from transfers on average), they are more affected by the wage decline. If low-income groups have a higher proportion of transfer incomes, they will bear a greater share of the tax burden from this. The wage and transfer income effects resulting from wage devaluation thus affect high- and low-income groups in opposite directions, and overall, these effects are estimated to be distributionally neutral.

Table 7.23. The average change in real disposable income due to consumer price changes across income deciles, per cent of total consumption

	1	2	3	4	5	6	7	8	9	10	Avg.
Model 1											
Direct price effects	-0.04	-0.03	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.01	-0.01	-0.02
Indirect price effects	0.13	0.11	0.10	0.10	0.09	0.08	0.08	0.08	0.08	0.07	0.09
Wage and transfer income effects	-0.36	-0.36	-0.36	-0.36	-0.36	-0.36	-0.36	-0.36	-0.36	-0.36	-0.36
Overall impact	-0.26	-0.28	-0.28	-0.28	-0.29	-0.29	-0.30	-0.30	-0.29	-0.30	-0.29
Gini coefficient	-	-	-	-	-	-	-	-	-	-	*0.00*
Model 2a											
Direct price effects	-0.02	-0.02	-0.02	-0.02	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Indirect price effects	0.08	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.04	0.05
Wage and transfer income effects	-0.20	-0.20	-0.20	-0.20	-0.20	-0.20	-0.20	-0.20	-0.20	-0.20	-0.20
Overall impact	-0.15	-0.16	-0.16	-0.16	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.16
Gini coefficient	-	-	-	-	-	-	-	-	-	-	*0.00*
Model 2b											
Direct price effects	-0.02	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01

Indirect price effects	0.05	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Wage and transfer income effects	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13
Overall impact	-0.10	-0.10	-0.10	-0.10	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.10
Gini coefficient	-	-	-	-	-	-	-	-	-	-	*0.00*
Model 3a											
Direct price effects	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Indirect price effects	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02
Wage and transfer income effects	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11
Overall impact	-0.09	-0.09	-0.09	-0.09	-0.10	-0.09	-0.10	-0.10	-0.09	-0.10	-0.09
Gini coefficient	-	-	-	-	-	-	-	-	-	-	*0.00*
Model 3b											
Direct price effects	-0.01	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	*-0.01*
Indirect price effects	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	*0.01*
Wage and transfer income effects	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04
Overall impact	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	*-0.03*
Gini coefficient	-	-	-	-	-	-	-	-	-	-	*0.00*

Notes: Households are categorised into income deciles based on their disposable income. The direct price effect covers price changes on dairy, vegetables, beverages, pork, cows, fish and poultry. The indirect price effect covers price changes on houses, cars, energy, services and other non-food products. Behavioural effects (substitution effects across products) are not included.
Source: Own calculations.

Effects on employment

Total employment in the economy will fall in the short term as a result of a CO_2-eq tax of DKK 750 per tonne on fertiliser, liming and livestock. Part of this is through the announcement of the tax, as the anticipation of a future tax will cause food companies and farmers to reduce investments. This lowers the demand for labour that produces capital goods for agriculture. The introduction of the tax reduces agricultural production, which reduces the demand for labour in agriculture. The weaker development of demand from capital goods and agriculture reduces the rate of wage growth. The relative wage decline, in turn, will gradually increase the demand for labour in the economy in general, with employment eventually rising back towards the starting point so that there are no significant structural changes in employment.

Table 7.24 shows which industries will experience the largest decreases in employment in 2030 in terms of full-time employees as a result of the tax. In particular, animal production and ancillary industries are estimated to experience the largest declines. This is a natural consequence of the significant tax base. The decline in employment in agriculture is offset by a corresponding increase in jobs elsewhere in the economy, which is why the employment migrations in *Table 7.24* are transitory.

Table 7.24. Employment effects in 2030 of CO_2-eq taxes on livestock and fertiliser, change in full-time employees

	Baseline in 2030	Model 1: DKK 750 per tonne of CO_2-eq (livestock and fertiliser)	Model 2a: DKK 750 per tonne of CO_2-eq with a base deduction of 50 per cent	Model 2b: DKK 750 per tonne of CO_2-eq with a base deduction of 50 per cent for livestock and restructuring of the hectare subsidy	Model 3a: DKK 250 per tonne of CO_2-eq or with a base deduction of 50 per cent for livestock and DKK 750 per tonne of CO_2-eq and base deduction on fertiliser	Model 3b: DKK 50 per tonne of CO_2-eq with a base deduction of 50 per cent for livestock and restructuring of the hectare subsidy
Number (per cent)						
Cattle	10,950	-2,150 (-19.7)	-1,200 (-11.1)	-1,050 (-9.5)	-700 (-6.3)	-500 (-4.6)
Crop	12,650	-1,350 (-10.8)	-900 (-7.1)	-400 (-2.9)	-700 (-5.5)	-200 (-1.6)
Pigs	7,300	-1,300 (-17.6)	-800 (-10.9)	-600 (-8.1)	-500 (-6.5)	-250 (-3.4)
Pig slaughterhouses	8,700	-1,200 (-13.8)	-750 (-8.5)	-550 (-6.3)	-450 (-5)	-250 (-2.7)
Dairies	6,050	-950 (-15.5)	-500 (-8.3)	-450 (-7.2)	-300 (-4.6)	-200 (-3.4)
Cattle slaughterhouses	1,100	-350 (-32.5)	-200 (-18.7)	-200 (-16.1)	-100 (-10.8)	-100 (-7.9)
Other food industry	11,300	-350 (-2.9)	-200 (-1.7)	-100 (-1)	-150 (-1.2)	-50 (-0.4)
Machine pools	2,800	-250 (-9.4)	-150 (-5.8)	-100 (-3.6)	-100 (-3.9)	-50 (-1.7)
Poultry	950	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)
Bakeries	13,000	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)
Poultry slaughterhouses	650	0	0	0	0	0

		(-)	(-)	(-)	(-)	(-)
Horticulture	1,950	50 (1.3)	0 (-)	0 (-)	0 (-)	0 (-)
Total	77,450	-7,950 (-10.2)	-4,800 (-6.1)	-3,400 (-4.3)	-3,050 (-3.8)	-1,650 (-2.0)

Note: Full-time employees are rounded to the nearest 50 people. The effects in the table are the change in the number of full-time employees in a given industry. Therefore, the table does not indicate specific migration flows between industries or whether the employment table in a particular industry consists of the same employees as before.
Source: Own calculations.

7.14 Effects on Land, Capital and Cultivation Value

The terms of reference state that the Expert Group must shed light on the economic consequences associated with the models, including the effects and impact on business. When a tax is imposed on agriculture, farmers' wealth is reduced through reduced land and capital value, and future earnings are reduced through increased operating costs. Subsidies can be used as a means to promoting technological change and development, thereby reducing the decline in land and capital value and the paradigm shift in business that may result from the application of taxes. The consequences for agriculture must be seen in the context of current regulation and the future overall regulation.

This section describes the effects on land, capital and cultivation value of introducing a CO_2-eq tax on agriculture corresponding to the Expert Group's three model types with effective taxes of DKK 750, 375 or 125 per tonne of CO_2-eq.

Effects on land and capital value

A tax on agriculture reduces the return that can be generated from a given amount of land and capital, causing a decline in the asset value of land and capital. The decline in profits can be mitigated if agriculture has technological reduction options that are cheaper than the tax, or if agriculture reduces the amount of fertiliser for the land in use (e.g. by changing the choice of crop). It should be noted that the total land value of agricultural land (both in operation and fallow land) is estimated to be DKK 210 bn in 2030 in the baseline.

Specifically, the calculations take the following into account: A tax results in less need for feed and less fertiliser. The lower demand for feed leads to a shift in crop production away from feed production, and the lower amount of fertiliser increases the price of fertiliser, which lowers the earnings of crop producers. This translates into lower land values.

Intra-agricultural market effects:

- **Tax on livestock leads to fewer animals**: The tax on animal husbandry lowers the earnings per animal, reducing the number of animals.
- **Fewer animals affect crop production:** Crop producers sell crops in the form of feed and bedding for livestock production, where there is limited competing imports. This means that a decrease in livestock production as a result of a CO_2-eq tax will reduce the production value of crop production and thus the contribution margin on land and capital, *see Tables 7.25 and 7.26*, if other crops with the same contribution margin cannot be produced. It reduces the land value for crop producers.

- **Reduced animal manure increases the price of fertiliser:** Livestock producers supply manure for crop production, and prices in this market affect profits on land and capital. A decline in livestock production due to a CO_2-eq tax will increase the price of livestock manure (due to the reduced supply), further lowering the contribution margin and thus the land value for crop producers.

Internal land market:

- **Organic and conventional agriculture are affected differently**: A uniform CO_2-eq tax will constitute a larger share of the production value in conventional crop production relative to organic crop production, which in isolation makes organic production relatively more profitable as a result of the tax. The conditions for organic area subsidy further restrict the use of organic fertilisers on organic areas compared to the current harmony requirement. This means that more organic areas are needed to spread the same amount of livestock manure, which is why a drop in land values will theoretically affect organic farmers relatively more. In addition, organic farmers cannot use feed additives that reduce emissions and the tax per animal.

Other demand:

- **Crops for food industries:** Crops are sold to food industries, directly for export and to other sectors of the economy (e.g. straw for energy production for the utilities sector). Thus, the contribution margin is affected by competitive conditions for both agriculture and food industries as well as the effects of a possible tax on the rest of the economy.

However, several of the Expert Group's tax models include subsidy schemes for land use change in the form of transition from agricultural land (grazing land or cropland) to wetlands or forest. In particular, the recommended subsidy for afforestation of 250,000 hectares, *see Section 3.3*, can have significant effects on land values:

1. **Effect of compensation**: Many of the lands that lose or have a reduced arable value after a tax could be converted to forest and receive income from subsidies. In addition, the compensation rate may be higher than the existing contribution margins on some land. This will collectively capitalise in the land values in an upward direction.

2. **Supply effect:** When land is converted to other land uses, the supply of crop rotation land is reduced. Less land in rotation increases the price of crops and harmony area, which capitalises in the land values in an upward direction. Increased supply of wood products due to increased forest area reduces the price of wood products, which capitalises in the land values in a downward direction. The result of afforestation, then, is that an immediate drop in price turns into an increase in land values that is higher than the subsidy given for afforestation.

Table 7.25. Change in land values in 2030 with different tax models

	Model 1	Model 2a	Model 3a
Tax on livestock, liming and fertiliser, per cent	-16.8	-6.2	-3.8
Tax on livestock and liming, per cent	-10.1	-7.3	-4.4

Tax on livestock, liming and fertiliser + subsidies for afforestation, per cent	-8.8	4.1	7.2

Note: The effect from subsidies for afforestation is under the assumption that the land converted to forest has an average cultivation value compared to agricultural land in rotation.
Source: Own calculations.

If a significant area is converted to afforestation, the demand for farm buildings and machinery will decrease, reducing the value of the current capital stock, *see Table 7.26.*

Table 7.26. Changes in capital value in 2030 with different tax models

	Model 1	Model 2a	Model 3a
Tax on livestock, liming and fertiliser, per cent	-13.7	-8.3	-5.0
Tax on livestock and liming, per cent	-11.0	-5.8	-2.7
Tax on livestock and fertiliser + subsidies for afforestation, per cent	-13.3	-8.1	-5.1

Note: The effect from subsidies for afforestation is under the assumption that the land converted to forest has an average cultivation value compared to agricultural land in rotation. Capital value is the present value of the future payments from the agricultural assets of buildings and machinery, i.e. the discounted value of future net payments that the assets are expected to generate in the normal course of business.
Source: Own calculations.

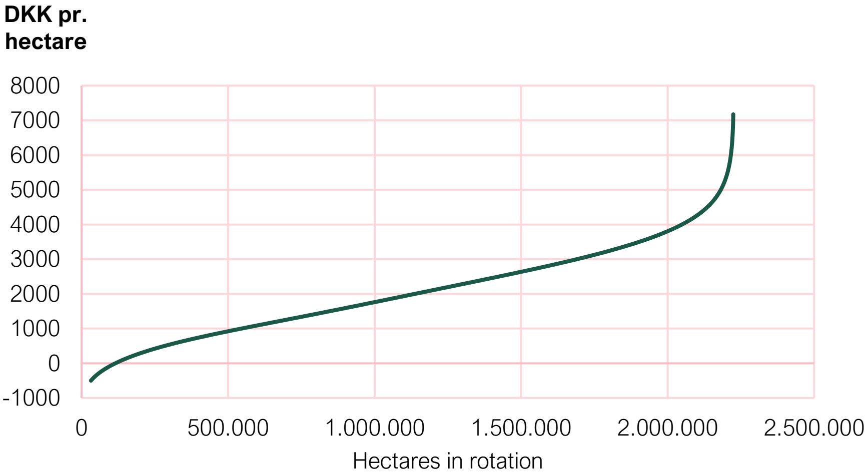
Effects on cultivation value

With the introduction of a CO_2-eq tax, there will be a direct decrease in the cultivation value per hectare, i.e. the return on land, by taxing fertiliser (after behavioural adjustment). As explained above, the CO_2-eq tax may also have other effects on the cultivation value via other channels, such as reduced animal production's importance for livestock manure and crop composition. If the cultivation value (plus any subsidies) falls below the value of the alternative use, it is expected that the land will switch to the alternative use.

Alternative uses other than cultivation would be afforestation, wetland restoration of carbon-rich agricultural land, renewable energy production or fallowing where the land has no productive use.

How much land is taken out of production depends on the spread in land productivity and how much the return on land is affected by a tax. There is a difference in the degree of productivity of soils that makes some soils more profitable to farm than others. *Figure 7.3* shows the cultivation value of land in rotation, as measured by the surplus it is estimated to generate. The difference in land yields has an impact on how farmers react to higher costs as a result of a CO_2-eq tax, including whether to stop cultivation on land with relatively low yields.

Figure 7.3. Supply curve for land – distribution of cultivation value per hectare per year



Note: Farming value is stated as contribution margin II, which is earnings minus variable and partially variable costs. It is based on 2013-18 prices. Cultivated land refers to land that is cultivated, whereas land that is not cultivated is used for other purposes (e.g. fallow land). Cultivated land makes up about 2.2 million hectares of the total agricultural area of about 2.7 million hectares.
Source: Own calculations and IFRO Documentation 2022 4.

7.15 Examples of Typical Farmers and Bankruptcy Risk

Type numbers and example calculations for average farm types

Below are a number of examples that illustrate an average farm's immediate impact at each of the tax levels (before behavioural response and adaptation). For this reason, the examples do not take into account that the farmer can, for example, reduce their tax burden by utilising technological means. In addition, the farmer is expected to be able to partially pass on the tax burden in higher sales prices, which reduces the burden.

Table 7.27 shows examples of figures for an average farm across farm types, including turnover, number of livestock and agricultural land. It should be noted that the farm types in *Table 7.27* do not correspond one-to-one to the emission sources in the modelling calculations in *Chapter 2*, as the model is broken down at the industry level and not by farm type, like the example calculations below. In the accounting data used for the example calculations, a single farm will be assigned to an overall farm type if it accounts for 50 per cent or more of the total standard output. For this reason, the economic burden of agricultural products can vary from farm to farm. For example, a cattle farm in *Table 7.27* will typically also have crop production and will therefore be affected by both a CO_2-eq tax on cattle and fertiliser usage.

Table 7.27. Description of average farm types (full-time farms)

	Crop, conv.	Crop, organic	Dairy cattle, conv.	Dairy cattle, organic	Fattening pigs, conv.	Piglets, conv.	Pigs, organic	Agriculture

Number	Unit	2,139	222	1,998	363	876	775	56	7,599
Revenue	DKK 1,000	5,132	3,734	10,067	10,593	12,405	17,194	10,655	9,307
Operating profit/loss[1)]	DKK 1,000	1,029	600	1,312	1,451	2,057	2,317	1,031	1,280
Emissions	Tonnes of CO_2-eq	246	130	2,052	1,690	739	849	380	957
- Of which from livestock	*Tonnes of CO_2-eq*	*19*	*26*	*1,863*	*1,538*	*576*	*702*	*287*	*773*
Number of cows	Yearling	1	1	242	199	0	1	0	74
Number of heifers	Yearling	1	4	222	187	1	1	0	69
Sows	Yearling	1	0	1	1	62	1,028	214	137
Fattening pig	Yearling	100	51	40	36	13,363	1,828	3,930	2,453
Area under grain	Hectares	198	107	48	61	163	161	112	135
Area under coarse feed	Hectares	17	45	136	185	7	7	42	56
Clay soil	Hectares	182	112	45	34	123	115	11	111
Sandy soil	Hectares	134	127	146	227	101	104	179	132

Note: Only full-time farms are included in the table. The operating branches in the table are a selection of the largest types of operating branches. There are other types of operating branches, such as other cattle, integrated pig farms and mixed farm types. The other types of agriculture are included in the column with agriculture. Revenue and operating profit are calculated based on averages over the period from 2017-2021. The number of livestock, emissions and amount of land are calculated based on 2021. Averages in the table are based on a sample from SEGES weighted up to the representative population in agriculture. Operating profit is calculated before owner remuneration and after financial expenses.
Source: Own calculations based on SEGES' accounting data.

Table 7.28 illustrates examples of the immediate tax burden for average farms (before adaptation and behaviour) across farm types. This is calculated based on type numbers from *Table 7.27*. The examples are calculated for models 1-3.

The immediate tax payment is gradually reduced from model 1 to model 3 as the effective tax rate is reduced. However, it is limited how much the immediate tax payment of crop farms is reduced from model 2a to model 3a, as the effective tax rate for fertiliser usage is unchanged in the two models. Across farm types, the average dairy farm has the largest immediate tax payment and thus the largest negative change in operating profit, which is due to the fact that dairy cattle have higher CO_2-eq emissions and thus a larger immediate tax payment as a result of a CO_2-eq tax. It should also be noted that the immediate burden is lower when restructuring direct agricultural subsidies (variant b) relative to a fertiliser tax with a base deduction (variant a).

Table 7.28. Example calculations with immediate burden and immediate change in result for different types of farms

	Crop, conv.	Crop, organic	Dairy cattle, conv.	Dairy cattle, organic	Fattening pigs, conv.	Piglets, conv.	Pigs, organic	Agriculture
Model 1: Tax of DKK 750 per tonne of CO_2-eq on fertiliser, liming and livestock								
Immediate burden (DKK 1,000)	185	98	1,539	1,268	554	637	285	718
Immediate change in operating profit (per cent)	-18	-16	-117	-87	-27	-27	-28	-56
Model 2a: Tax of DKK 750 per tonne of CO_2-eq on fertilisers, liming and livestock, incl. a base deduction of 50 per cent								
Immediate burden (DKK 1,000)	92	49	770	634	277	318	143	359
Immediate change in operating profit (per cent)	-9	-8	-59	-44	-13	-14	-14	-28
Model 2b: Tax of DKK 750 per tonne of CO_2-eq with a base deduction of 50 per cent for livestock and restructuring of the hectare subsidy								
Immediate burden (DKK 1,000)	21	16	710	586	226	272	113	301
Immediate change in operating profit (per cent)	-2	-3	-54	-40	-11	-12	-11	-24
Model 3a: Tax of DKK 250 per tonne of CO_2-eq on livestock and DKK 750 per tonne of CO_2-eq on fertilisers and liming, incl. a base deduction of 50 per cent								
Immediate burden (DKK 1,000)	88	42	304	249	133	143	71	166
Immediate change in operating profit (per cent)	-9	-7	-23	-17	-6	-6	-7	-13
Model 3b: Tax of DKK 250 per tonne of CO_2-eq with a base deduction of 50 per cent for livestock and restructuring of the hectare subsidy								

Immediate burden (DKK 1,000)	17	10	245	202	82	97	42	108
Immediate change in operating profit (per cent)	-2	-2	-19	-14	-4	-4	-4	-8

Note: Only full-time farms are included in the table. The calculations are based on the effective tax rate and type numbers from Table 7.27.
Note: Operating profit is before owner remuneration and calculated as an average for 2017-2021
Source: Own calculations based on SEGES' accounting data.

Example calculations of effects on bankruptcy risk at different tax levels

An analysis has been made of the consequences of the presented models for full-time farms on the immediate bankruptcy risk of the farms.

As a starting point, 6 per cent of the total turnover in agriculture is estimated to be among farms at high risk of bankruptcy. *Table 7.29* shows an estimate of the proportion of turnover in agriculture that immediately moves into farms at high risk of bankruptcy in each of the models presented. This includes the immediate burden of the CO_2-eq tax and change in capital value (incl. afforestation). Price and volume adjustments are not taken into account in the calculations.

Table 7.29. Immediate changes in bankruptcy threat, in per cent of revenue

	Model 1	Model 2a	Model 2b	Model 3a	Model 3b
Crops	6	1	0	-1	-1
Cattle	25	11	10	1	1
Pigs	12	2	2	0	0
Other livestock	7	0	0	0	-1
Mixed	1	0	0	0	0
Full-time overall	**15**	**5**	**4**	**0**	**0**

Note: The calculations for changes in the threat of bankruptcy take into account the immediate capital income effect of the introduction of the CO_2-eq tax and technological reduction options. Adjustment is thus not taken into account.
Source: Own calculations based on SEGES accounting data

In agriculture, there are approx. 7,600 full-time farms, of which it is estimated that approx. 360 farms are at high risk of bankruptcy to begin with. *Table 7.30* shows an estimate of the number of farms that would immediately become at high risk of bankruptcy in each of the models presented. This includes the immediate burden of the CO_2-eq tax and change in capital value (incl. afforestation). Price and volume adjustments are not taken into account in the calculations.

Table 7.30. Immediate changes in threat of bankruptcy, number of farms

	Model 1	Model 2a	Model 2b	Model 3a	Model 3b
Crops	230	90	70	50	50

Cattle	590	240	240	20	<20
Pigs	200	30	30	0	0
Other livestock	<20	0	0	0	0
Mixed	<10	0	0	0	<10
Full-time overall	**1,040**	**360**	**340**	**70**	**70**

Note: The calculations for changes in the threat of bankruptcy take into account the immediate capital income effect of the introduction of the CO_2-eq tax and technological reduction options. Adjustment is thus not taken into account.
Source: Own calculations based on SEGES accounting data

Example calculation for a tax of DKK 125 per tonne of CO_2-eq after adjustment
The following is an example calculation for model 3a, i.e. an effective tax rate of DKK 125 per tonne of CO_2-eq for livestock and DKK 375 per tonne of CO_2-eq for fertiliser usage, where the consequences for livestock and crop producers after adjusting production are also examined. It should be noted that the threat of bankruptcy does not mean that the farm is actually going bankrupt. Farms may well be at risk of bankruptcy for several years. *Box 7.13* describes the used definition of the risk of bankruptcy.

Box 7.13

Definition of threat of bankruptcy

The threat of bankruptcy is defined as a situation in which farms need liquidity but have a debt ratio that makes this difficult. The bankruptcy situation is thus determined by two factors: the debt ratio and liquidity. The debt ratio is calculated as the debt's share of the total asset value, while liquidity corresponds to the result after financing, depreciation, amortisation and owner remuneration, including non-agricultural income. Liquidity is made into a general measure by relating it to gross proceeds (revenue).

Four levels of bankruptcy threat are used: Strongly at risk of bankruptcy, at risk of bankruptcy, somewhat at risk of bankruptcy and not at risk of bankruptcy. 'Strongly at risk of bankruptcy' means a debt ratio of over 100 per cent (insolvency) and a negative liquidity. However, prolonged negative earnings that erode equity can lead to more farms being at risk of bankruptcy in the future. Conversely, 'not at risk of bankruptcy' means that a farm has equity and/or a result that means it is not in immediate difficulty. In between these two situations are 'at risk of bankruptcy' and 'at risk of bankruptcy to a lesser extent', which are characterised by combinations of debt ratios and liquidity, which can make farms vulnerable to declines in earnings or in asset values.

The analysis focuses on how many more farms are threatened with bankruptcy based on the different tax levels. A tax will have an effect on both the debt ratio via decreases in land and other asset values and on liquidity due to the increased cost.

Full-time farms and not part-time farms are analysed in terms of bankruptcy risk, as full-time farms are expected to be run professionally, while part-time/hobby farms may have other purposes. This is based on accounting figures for 2021 from SEGES' accounting database, where a cyclical smoothing of turnover has been made on the basis of the period 2015-21.

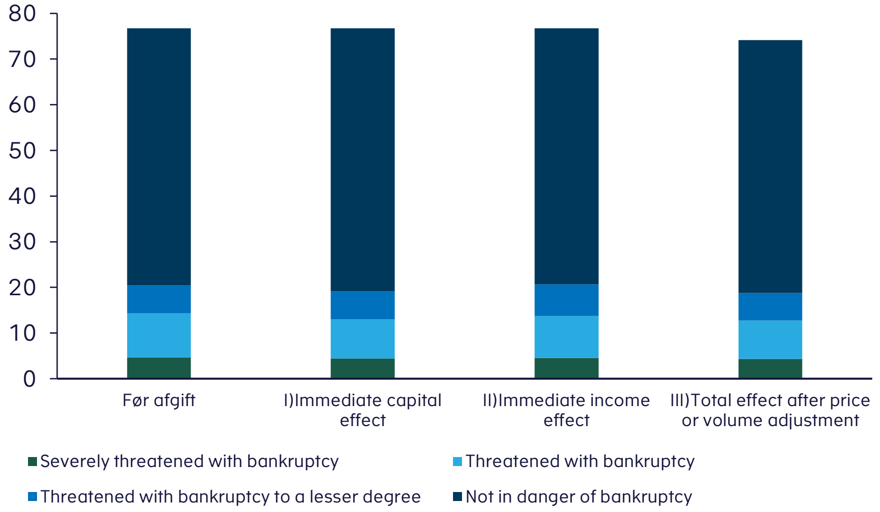
The analysis shows that 360 farms, corresponding to approx. 5 per cent of farms, are at high risk of bankruptcy before a tax is introduced, and these farms account for 6 per cent of turnover. Basically, 1,630 farms, corresponding to 21 per cent of the farms, are at risk of bankruptcy to a lesser or greater extent, and these farms account for 27 per cent of the turnover.

The immediate effects have been calculated as a result of the following:

1. *Immediate capital effect of a CO_2-eq tax:* With the introduction of a CO_2-eq tax, farms are expected to experience a capital loss in the form of loss of value of land and other assets (e.g. machinery and buildings). A significant part of the capital loss can be expected at the time of the announcement.
2. *Immediate income effect of the introduction of the CO_2-eq tax and technological reduction options:* Agricultural enterprises' costs increase as a result of the CO_2-eq tax, and the technological reduction options that are immediately expected to be used in the event of a tax (feed additives, etc.) are included.
3. *Short-term effect with price and volume adjustment:* This step includes increases in sales prices and decreases in production volumes. The price and volume correction is calculated so that it occurs proportionally on all farms. This will not be a realistic adjustment, but shows in a stylised way how a farm will be affected by the average volume adjustment (production decline).

The total turnover in agriculture varies over the years, but in recent years it has been in the region of DKK 80-85 bn. Based on data for 2021, where the business cycle is levelled out, agricultural turnover in the baseline before the introduction of the tax is calculated at DKK 77 bn. Figure 7.4 shows an estimate of the expected development in total revenue by bankruptcy risk for the immediate capital effect (I), immediate income effect (II) and short-term effect with price and volume adjustment (III). It can be seen that the share of the total turnover of farms threatened with bankruptcy (6 per cent) is unchanged after the introduction of the tax. Although the tax in isolation has a negative impact on earnings and assets in the form of buildings etc., there is a parallel increase in asset value in the form of an increase in the land values of 7.2 per cent, *see Table 7.25 in Appendix 7.14*, as a result of, among other things, subsidies for afforestation, which can have significant effects on the land values, which overall mitigates the impact on bankruptcy risk.

Figure 7.4 Development in total revenue by bankruptcy risk, DKK bn.



Note: The figure shows examples of how the gross dividend is distributed by bankruptcy risk for different scenarios in the calculations. In step III, price and volume adjustments are taken into account. This results in a volume decline of DKK 6 bn, which is assumed to be distributed equally across all farms.
Source: Own calculations based on SEGES accounting data

Table 7.31 shows that the share of revenue distributed in farms threatened with bankruptcy is generally unchanged as a result of a tax of DKK 125 per tonne of CO_2-eq.

Table 7.31. Share of total turnover distributed in farms highly threatened with bankruptcy at a CO_2-eq tax of DKK 125 per tonne (per cent)

Branches of operation	0) Before tax	I) Immediate capital effect	II) Immediate income effect	III) Total effect after price and volume adjustment
Crops	1	3	3	3
Cattle	13	12	12	12
Pigs	3	3	3	3
Other livestock	4	4	4	4
Mixed	0	0	0	0
Full-time overall	6	6	6	6

Note: The table shows the figures for all full-time farms.
Source: Own calculations based on SEGES' accounting data.

In the long term, volume and price adjustments are expected. The volume adjustment can be done by the individual farms reducing their production or by certain farms stopping altogether, for example, in connection with a bankruptcy. With lower production, agriculture can pass on some of the cost increases to the selling price. For calculation purposes, it is assumed that the price and volume correction takes place for all farms with a proportional reduction, and that no specific farms take the volume decline. The scenario includes a reduction in revenue corresponding to 3 per cent in model 3a when price and volume adjustments are taken into account. Looking at the volume adjustment alone, the reduction in production corresponds to a reduction in the number of farms by 450.

There is great uncertainty about how large a proportion of farms will actually go bankrupt and how the tax will affect the remaining existing farms. A farm can be threatened with bankruptcy for many years without necessarily going bankrupt. Often, the farm will be bought and continued, and there may therefore be a restructuring or change in production on the individual farm, and thus a bankruptcy for the individual farmer does not necessarily mean a decline in production for agriculture as a whole. Thus, there is not necessarily a direct correlation between the number of farms, the increased threat of bankruptcy from a tax and the structural effect, understood as a structural decline in production as a result of a tax.

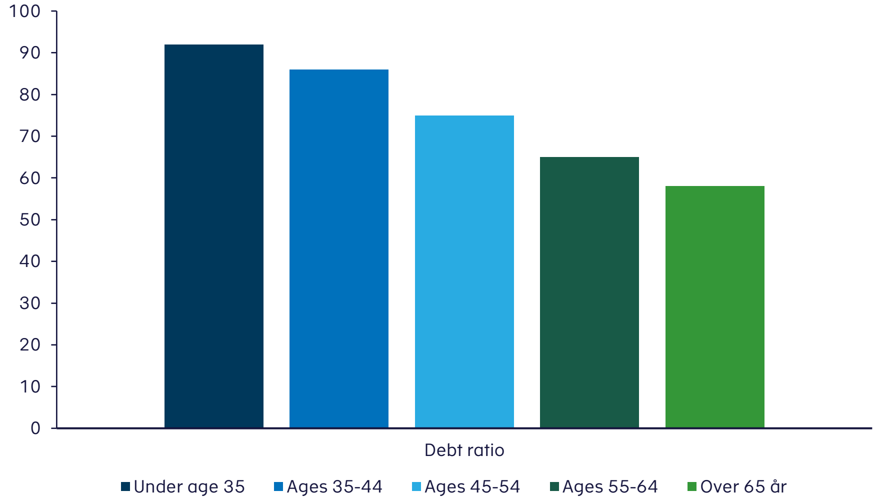
Considerations on the debt structure of farms

There is a close correlation between the age of farmers and the debt ratio of farms, with young farmers typically having higher debt than older farmers, *see Figure 7.5*. This may be due to both the fact that younger farmers have invested more in the farm and that they have had the farm for a shorter number of years after the takeover and therefore have not had as many years to consolidate the farm. If there is not a strong enough correlation between higher debt ratios and increased productivity/lower CO_2-eq emissions, there is a risk that farms with high debt ratios will become bankrupt with the introduction of a tax. This can increase the risk of bankruptcy among younger/newly established farmers.

Conversely, there may be a tendency for the most productive/climate-efficient farms to also be among those with the highest debt ratio. This may be because older production facilities have a positive contribution margin and can, therefore, make operations profitable if the debt is low, while it may not necessarily be profitable to invest in new facilities on the farm in question, e.g. due to a lack of scale. It will often be an older farmer who runs these farms. Against this background, there may also be a correlation between age, low debt ratio and age of production facilities. A tax on CO_2-eq emissions can reduce the contribution margin of these plants to such an extent that these types of farms are not profitable, even if the debt is low.

The Expert Group has not had the opportunity to make an assessment of the prevalence of the two illustrated correlations, which is why it is difficult to assess in advance how the structural change will be put together.

Figure 7.5. Debt ratios for full-time farms in 2021 by age of owner



Source: Own calculations based on SEGES accounting data

Geographical impact

The following shows the estimated decline in gross value added across regions for each of the Expert Group's main models, *see Table 7.32*. In all regions of the country, agriculture accounts for a limited share of production, which is why all models have a limited effect on the geographical income balances in Denmark.

Table 7.32. Decline in GVA across regions due to production decline in primary agriculture

	GVA in the starting point			Decline in GVA, share of total GVA, per cent				
Region:	**Total (DKK million)**	**Agriculture (DKK million)**	**Agriculture's share of total**	**Model 1**	**Model 2a**	**Model 2b**	**Model 3a**	**Model 3b**

			GVA (Per cent)					
The city of Copenhagen	589,800	0	0.0	0.0	0.0	0.0	0.0	0.0
Greater Copenhagen	357,700	100	0.0	0.0	0.0	0.0	0.0	0.0
North Zealand	155,800	300	0.2	0.0	0.0	0.0	0.0	0.0
Bornholm	10,500	400	3.8	0.9	0.6	0.3	0.4	0.2
East Zealand	68,700	400	0.6	0.2	0.1	0.1	0.1	0.0
West and South Zealand	153,200	4,100	2.7	0.7	0.4	0.2	0.3	0.1
Funen	150,300	2,900	1.9	0.5	0.3	0.2	0.2	0.1
South Jutland	286,600	5,700	2.0	0.5	0.3	0.2	0.2	0.1
East Jutland	332,200	4,100	1.2	0.3	0.2	0.1	0.1	0.1
West Jutland	167,200	7,500	4.5	1.1	0.7	0.4	0.5	0.2
North Jutland	189,600	4,400	2.3	0.6	0.4	0.2	0.3	0.1
Total	**2,461,600**	**29,900**	**1.2**	**0.3**	**0.2**	**0.1**	**0.1**	**0.1**

Note: GVA in the starting point is the 2022 figure from Statistics Denmark. The decline in GVA is estimated for 2030. The calculations do not take into account any change in GVA due to production decline in the secondary industry.
Source: Own calculations.

7.16 Financial Stability

The financial risks associated with a CO_2-eq tax have been assessed by Danmarks Nationalbank in connection with the preparation of this report. It is assessed that Danish banks and mortgage credit institutions are generally well-equipped to handle the potential losses that may arise as a result of a CO_2-eq tax on agriculture. This is due to, among other things, a high level of security in the underlying mortgages and ongoing earnings.

However, there are differences between the individual institutions' exposures to farms threatened with bankruptcy. Danmarks Nationalbank finds that individual institutions may need to utilise their excess capital adequacy to cover potential losses. However, this depends on which tax rate is adopted politically, as well as the extent of compensation. If the proceeds of a tax are returned directly to the industry, the risk of loss for the institutes will be significantly reduced. The overall methodology behind the analysis is described in *Box 7.14*.

A gradual implementation of the tax, e.g. from 2027 to 2030, would be favourable for financial stability. This allows institutions to absorb potential losses over several years with current earnings, and fewer credit institutions will therefore need to utilise their excess capital adequacy. In addition, it gives institutions more time to adjust their capital planning and business model, and agricultural customers more time to adapt their production.

Box 7.14

Summary of Danmarks Nationalbank's analysis of financial risks associated with the introduction of a CO_2-eq tax on agriculture

Danmarks Nationalbank's calculations are based on, among other things, accounting data from a proportion of Danish farms for the period 2019-2021. The derived consequences of a CO_2-eq tax, such as a drop in asset prices on land and buildings, are based on calculations in GreenREFORM, which is an environmental and climate economic model for the Danish economy developed by DREAM.

The analysis consists of calculating the exposures of banks and mortgage credit institutions to farms threatened with bankruptcy as a result of a CO_2-eq tax. At the same time, the institutions' ability to cover potential losses on lending is assessed. A portion of the potential loss on loans to farms threatened with bankruptcy will already be recognised as impairment losses reserved to cover expected losses on the loans. At the same time, the institutions have a significant security in the underlying mortgages. Credit institutions have two additional defences against potential losses. Firstly, the institution's current earnings can cover the loss. If current earnings are not sufficient, the institution will then utilise its excess capital adequacy. Excess capital adequacy is the excess capital that an institution has available over and above the capital requirement that the institution is required to hold by the authorities.

7.17 Description of Export Elasticities

This section explains how export elasticities in the calculations are determined and the magnitudes of the elasticities used in the sensitivity analyses.

The size of export elasticities is important as the demand for output from a given industry is often dominated by the reaction of foreign trade when dealing with a small open economy like Denmark. Industry-specific elasticities describe the reaction in exports, and the reaction in imports is described by substitution between Danish and imported goods and services from the same industry in the outermost branching of the consumption functions. [78]

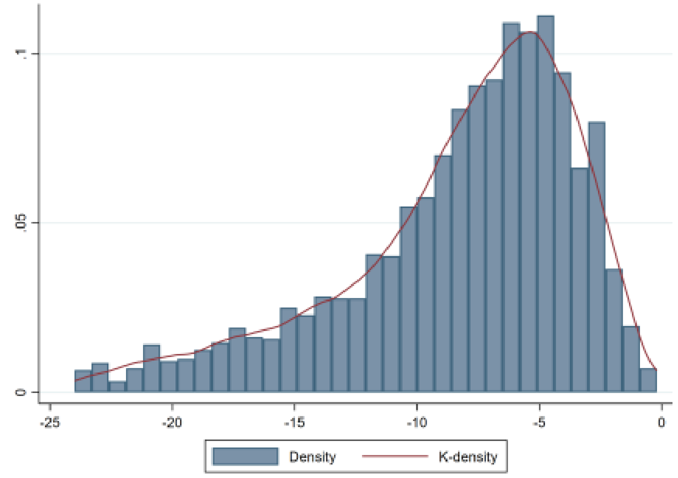
[78] Kirk, J. S. and Hansen, K. H. (2023). "Elasticiteter og markedsvilkår i GrønREFORM" (Elasticities and market conditions in GreenREFORM)

Fontagné et al. (2022)

The Expert Group has chosen to base its impact assessments on Fontagné et al. (2022). [79] The export elasticities from Fontagné et al. (2022) are based on a tariff study and should reflect the long-term elasticity. Fontagné uses IV cross-sectional analysis to estimate trade elasticities at the product level, where tariffs are the instrument for price differences. Tariff rates generally vary between 0-20 per cent and can thus be compared to the relevant cost shocks in the Expert Group's models. Data covers tariffs and trade flows in the period 2001-2016 between 189 exporting countries and 152 importing countries across 5,052 product categories (HS6 grouping). As tariffs are very consistent over time, these estimates can be considered true structural long-term assessments.

Figures 7.6 and *7.7* show that Fontagné's estimated elasticities are generally between 3 and 10.

Figure 7.6. Fontagné distribution of export elasticities for all industries



Note: The graph shows the distribution of export elasticities in Fontagné et al. (2022).
Source: Fontagné, L., Guimbard, H., and Orefice, G., (2022) 'Tariff-based product-level trade elasticities', Journal of International Economics.

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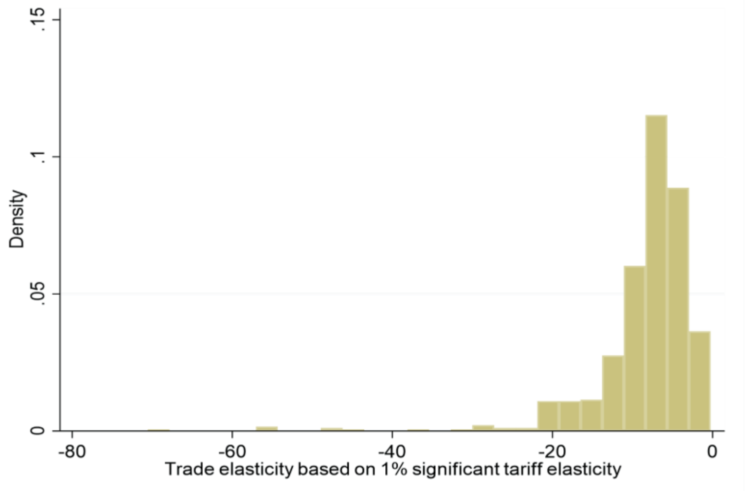
[79] See, for example, Fontagné, L., Guimbard, H., and Orefice, G., (2022) 'Tariff-based product-level trade elasticities', Journal of International Economics.

Figure 7.7. Fontagné distribution of elasticities for agriculture



Note: The graph shows the distribution of export elasticities in Fontagné et al. (2022) for agriculture and food production.
Source: Fontagné, L., Guimbard, H., and Orefice, G., (2022) **'Tariff-based product-level trade elasticities'**, Journal of International Economics.

The export elasticities for goods-producing industries are determined based on export elasticities (on 6-digit product codes) from Fontagné et al. (2022), which are weighted together to industry level based on the distribution of each industry's exports on the same products as in the national accounts. The industry-specific average export elasticities for agriculture and the food industry are shown in *Table 7.33*.

Table 7.33. Average export elasticities of the agriculture and food industry in the Expert Group's impact assessments

	Average elasticity	Export share
Crop production, conventional	5.36	21.5%
Crop production, organic	5.36	21.1%
Horticulture	7.50	17.2%
Cattle farming	8.11	2.6%
Pig farming	6.41	26.9%
Poultry	6.41	17.2%
Dairy	5.46	50.7%
Bakery	6.67	21.2%
Other food industry	6.93	36.9%
Slaughterhouse, cattle	5.69	53.1%
Slaughterhouse, pigs	12.10	61.3%
Slaughterhouse, poultry	5.84	27.6%

Note: The export elasticities shown are weighted together to industry level based on export estimates at product level. The export estimates at the product level mask a large underlying variation. Note also that the estimates for the animal industries are largely the same for organic and conventional producers, which is why only one overall estimate is reported for these despite the division in GreenREFORM.

Source: BACI database80 and Fontagné, L., Guimbard, H., and Orefice, G., (2022) 'Tariff-based product-level trade elasticities', Journal of International Economics

The average export elasticities mask a large underlying variation in export elasticities at the product level. In the dairy industry, for example, the average elasticity is 5.46, which means that drinking milk has an estimated export elasticity of close to 10 (lower market power) compared to butter and cheese, which have estimated export elasticities of around 3 and 5 (higher market power). Meat powder, residual products (such as tongues), etc. all have an elasticity above 20. However, weighted together, the export elasticities will be between approx. 5-10. Only 9 per cent of Danish agricultural exports are estimated to have an export elasticity above 15 and 2 per cent above 20 in Fontagné et al. (2022).

The variation can partly be explained by differences in transport costs and shelf life, as it can be seen that milk powder and meat powder have the highest elasticity values for dairies and slaughterhouses, respectively. In addition, differences in brand and bulk goods can also explain parts of the variation, as, for example, milk and meat powder must be described as bulk goods.

The size of the average export elasticities harmonises well with the general level of goods export elasticities and the empirical literature in general. See, for example, Hertel et al. (2007)[81] and a review of the literature by Boehm et al. (2023)[82] and Anderson et al. (2004)[83].

As the Expert Group's estimated export elasticities are assessed to be structural/long-term, a certain amount of inertia in the consumption reaction should, in principle, be taken into account based on the expectation that the short-term elasticity is smaller than the long-term. The Expert Group has not had access to data on the speed of consumption reactions for food exports and has therefore disregarded export inertia in the calculations. In the MAKRO modelling, work is underway to estimate export inertia for the Danish economy as a whole, but these are not necessarily accurate for food exports, which are expected to have faster consumer reactions than other exports (of medicine, furniture, machinery, etc.). If the preliminary assumptions from MAKRO's export inertia are used in the Expert Group's assumptions, this would result in a maximum decrease in reductions in 2030 of 0.2 million tonnes in model 1, 0.1 million tonnes in model 2 and less than 0.1 in model 3. Export inertia is thus not considered to have significant implications for the models in practice, but will need to be addressed in the future model development in Green-REFORM.

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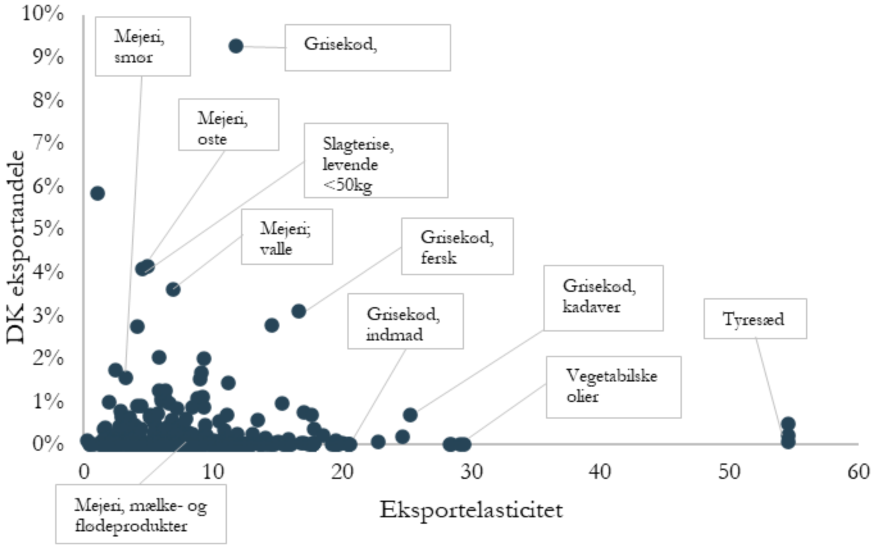
[80] The database is documented in **BACI: International Trade Database at the Product-level: The 1994-2007 Version**

[81] Hertel, Thomas, Hummels, David, Ivanic, Maros, Keeney, Roman, (2007) '**How confident can we be of CGE-based assessments of Free Trade Agreements?**', Economic Modelling.

[82] Boehm, Christoph E., Andrei A. Levchenko, and Nitya Pandalai-Nayar. "**The Long and Short (Run) of Trade Elasticities.**" American Economic Review 113.4 (2023): 861-905. Note that Boehm et al. (2023) themselves find significantly lower elasticities.

[83] Anderson, James and Eric van Wincoop. 2004. "**Trade Costs.**" Journal of Economic Literature 42 (3):691–751.

Figure 7.8. Estimates of export elasticity by product group, primary and food industry (Expert Group's central estimates based on Fontagné et al. (2022))



Note: The graph shows the distribution of export elasticities in Fontagné et al. (2022) for agriculture and food production in relation to the Danish export shares of total Danish agricultural and food exports.
Source: Fontagné, L., Guimbard, H., and Orefice, G., (2022) '**Tariff-based product-level trade elasticities**', Journal of International Economics. **BACI: International Trade Database at the Product-level: The 1994-2007 Version**

Feenstra et al. (2018)

In previous publications[84], GreenREFORM has estimated the export elasticities for goods-producing industries at detailed product level (6-digit product codes), based on Feenstra's method.[85]

Figures 7.9 and *7.10* show that the average export elasticity for dairies and slaughterhouses masks a large underlying variation in export elasticities at the product level. *Figure 7.9* shows that almost 50 per cent of dairy exports consist of cheese, while butter and milk powder account for around 10 per cent of exports. *Figure 7.10* shows that approx. 2/3 of slaughterhouse exports consist of fresh and frozen pork.

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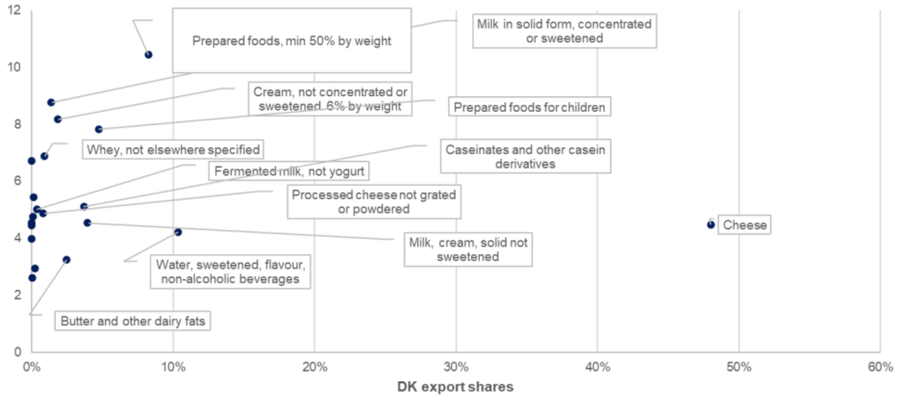
[84] See "Elasticiteter og markedsvilkår i GrønREFORM" (Elasticities and market conditions in GreenREFORM), and "**Estimering af udenrigshandelselasticiteter i MAKRO" (Estimation of foreign trade elasticities in MACRO), Kronborg, Poulsen and Kastrup 2020** for documentation of the estimation method

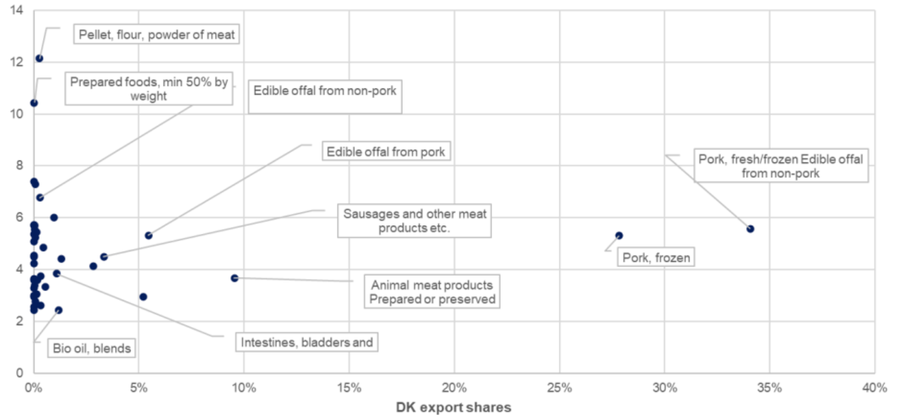
[85] Feenstra, R., Luck, P., Obstfeld, M. and Russ, K. (2018), 'In Search of the Armington Elasticity', Review of Economics and Statistics 100(1), 135-150. and Feenstra, R. C. (1994), 'New product varieties and the measurement of international prices', American Economic Review 84, 157–177.

Figure 7.9. Estimated product-specific export elasticities for dairies
(Feenstra's method)



Note: The graph shows the distribution of export elasticities in Fenstra et al. (2018) for agriculture and food production in relation to the Danish export shares of total Danish agricultural and food exports.
Kilde: Feenstra, R., Luck, P., Obstfeld, M. and Russ, K. (2018), 'In Search of the Armington Elasticity', Review of Economics and Statistics 100(1), 135–150, and Feenstra, R. C. (1994), 'New product varieties and the measurement of international prices', American Economic Review 84, 157-177. "Elasticiteter og markedsvilkår i GrønREFORM" (Elasticities and market conditions in GreenREFORM), and **BACI: International Trade Database at the Product-level: The 1994-2007 Version**

Figure 7.10. Estimated product-specific export elasticities for slaughterhouses (Feenstra's method)



Note: The graph shows the distribution of export elasticities in Fenstra et al. (2018) for agriculture and food production in relation to the Danish export shares of total Danish agricultural and food exports.

Kilde: Feenstra, R., Luck, P., Obstfeld, M. and Russ, K. (2018), 'In Search of the Armington Elasticity', Review of Economics and Statistics 100(1), 135–150, and Feenstra, R. C. (1994), 'New product varieties and the measurement of international prices', American Economic Review 84, 157-177. "Elasticiteter og markedsvilkår i GrønREFORM" (Elasticities and market conditions in GreenREFORM), and **BACI: International Trade Database at the Product-level: The 1994-2007 Version**

Feenstra's method calculates averages (moments) over time. Therefore, the estimated elasticity can be interpreted as a weighted average of the short and long term ('medium-term'). The data used (BACI) covers the period 1995-2020 (25 years). Thus, the effect may be lower than the "pure" long-term elasticity. Fontagné et al. (2022) use an IV cross-sectional analysis to estimate trade elasticities at the product level, where tariffs are the instrument for price differences. As tariffs are very consistent over time, these estimates can be considered true structural long-term assessments. For the agricultural sector, Fontagné et al. (2022) find estimates that are approx. 20-30 per cent higher than Feenstra's method.

A new study by Boehm et al. (2023), *The Long and Short (Run) of Trade Elasticities,* estimates export elasticities based on event studies of tariff changes. They generally find low elasticities (in the order of 2 in the long run) and generally argue that Feenstra and previous studies overestimate trade elasticities by not including bilateral fixed effects.[86] Their cross-sectional estimates (excluding bilateral fixed effects) of trade elasticities are between 4-7 (consistent with Feenstra, Fontagné and other previous studies). However, the lower estimates for bilateral fixed effects may also be due to a general attenuation bias increase in the event study specification.[87]

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[86] Including bilateral fixed effects means that a constant for the countries' existing trade between each other is included in the regression to account for unobservable constant bilateral trade preferences between the countries. This will need to be taken into account in its estimation if there is a correlation between trade preferences and tariff levels, as it will lead to omitted variable bias. These challenges will arise, for example, if you have scenarios where consumers in a given importing country have very strong preferences for a product from a specific exporting country, causing the importing country's policies to set a lower tariff on these products.

[87] Attenuation bias describes a situation where one's estimates tend towards 0, due to the signal vs. noise ratio increasing as more variables (in this case, fixed effects) are increased. See e.g. **https://towardsdatascience.com/biased-model-coefficients-part-1-2722128b9e1c**.

However, the focus in Boehm et al. (2023) is not the level of elasticity so much as the time response function. From this, it can be seen that the long-term effect occurs after about 7-10 years and that the short-term elasticity is about half of the long-term elasticity. Since Feenstra's method is interpreted as a weighted average of the short and long-term, the Boehm et al. time response function implies that Feenstra's elasticities can be increased.

On this basis, the Expert Group has chosen to use the Fontagné et al. (2022) estimate as a basis (weighted according to Danish export shares), but at the same time include a sensitivity analysis with estimates based on Feenstra, *see Section 2.7*. The Expert Group notes that there are no significant differences in the impact assessment in this sensitivity analysis.

Empirical studies on the size of export elasticities

Table 7.34 provides an overview of estimated export elasticities for the food industries. In general, the weighted elasticities vary in the range of 5-10[88] across estimations.

Table 7.34. Overview of the literature on export elasticities in the food industry.

	Hertel et al. (2007) (GTAP)	Expert Group / Fontagné (2022)	Feenstra et al. (2018) / GreenREFORM (2023)
Export elasticity			
Crop production, conventional	2.6-8.9	5.36	4.14
Crop production, organic	2.6-8.9	5.36	2.97
Horticulture	3.7	7.50	3.14
Cattle farming	4.0	8.11	3.89
Pig farming	4.0	6.41	4.01
Poultry	4.0	6.41	8.47
Dairy	7.3	5.46	5.36
Bakery	2.6-8.9	6.67	9.66
Other food industry	2.3-6.6	6.93	5.60
Slaughterhouse, cattle	7.7-8.8	5.69	4.98
Slaughterhouse, pigs	7.7-8.8	12.10	4.98
Slaughterhouse, poultry	7.7-8.8	5.84	4.98

Source: "Elasticiteter og markedsvilkår i GrønREFORM" (Elasticities and market conditions in GreenREFORM), Fontagné, L., Guimbard, H., & Orefice, G. (2022). Tariff-based product-level trade elasticities. Journal of International Economics, 137, 103593 and Hertel, Thomas, Hummels, David, Ivanic, Maros, Keeney, Roman, (2007) 'How confident can we be of CGE-based assessments of Free Trade Agreements?', Economic Modelling.

Import elasticities

The elasticity of substitution between Danish produced and imported consumption is determined based on the "rule of two", whereby the import elasticity of substitution is set to the same as the export elasticity for the supplying industry divided by 2.

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[88] See previously issued memo "Elasticiteter og markedsvilkår i GrønREFORM" (Elasticities and market conditions in GreenREFORM), and "**Estimering af udenrigshandelselasticiteter i MAKRO" (Estimation of foreign trade elasticities in MACRO), Kronborg, Poulsen and Kastrup 2020** for documentation of the estimation method

There is good empirical evidence for the 'rule of two'. This is similar to the approach in the MAKRO and REFORM model, and implies that consumers have a preference for domestically produced goods. Feenstra (2018)[89] finds that the rule of two can only be rejected for 20 out of 98 products, Hilberry and Hummels (2012)[90] emphasise that the rule of two is frequently used in CGE models, including GTAP. In *Section 2.7*, sensitivity analyses are performed without the rule-of-two.

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[89] In Search of the Armington Elasticity, Feenstra et al. (2018).

[90] "Elasticiteter og markedsvilkår i GrønREFORM" (Elasticities and market conditions in GreenREFORM), Kirk and Hansen, and "Estimering af udenrigshandelselasticiteter i MAKRO" (Estimation of foreign trade elasticities in MACRO), Kronborg, Poulsen and Kastrup 2020 for documentation of the estimation method

7.18 Other Model Results

Tax base and immediate burden

Table 7.35 shows a comparison of the immediate burden per animal group for models 1-3.

Table 7.35. Tax base and immediate burden divided by animal groups

	Tax base	Immediate burden			Burden per animal		
		Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
	m tonnes	*DKK million*			*DKK per animal*		
Dairy cows	3.08	2,200	1,100	375	4,200	2,100	700
Other cattle	1.44	1,025	525	175	1,000	500	175
Fattening pigs	0.98	700	350	125	25	25	0
Yearling sows	0.41	300	150	50	325	150	50
Piglets	0.23	175	75	25	5.00	2.50	0.75
Horses	0.15	100	50	25	600	300	100
Sheep	0.04	25	25	0	350	175	50
Broiler chickens	0.03	25	0	0	0.25	0.00	0.00
Lambs	0.02	25	0	0	125	50	25
Hens	0.02	0	0	0	1.25	0.50	0.25
Deer	0.01	0	0	0	900	450	150
Goats	0.01	0	0	0	375	175	50
Ducks, geese and turkeys	0.00	0	0	0	3.75	1.75	0.50
Pheasants (hens)	0.00	0	0	0	25	25	0
Pheasants (chicks)	0.00	0	0	0	0.50	0.25	0.00
Ostriches	0.00	0	0	0	3,250	1,625	550
Overall	**6.43**	**4,575**	**2,300**	**775**	**25**	**0**	**0**

Note: Immediate burden and burden per animal are given in the 2023 level. Immediate burden is rounded to the nearest DKK 25 million, while burden per animal is rounded to the nearest DKK 25, except for piglets, broilers, chickens, ducks, geese, turkeys and fanatics (chickens) where burden per animal is rounded to the nearest DKK 0.25. It is assumed that the taxes are continuously indexed with the general price level.

Source: Own calculations based on *Climate Status and Outlook 2023*.

Yearly effects tables

This section presents tables of the models' public costs and CO$_2$-eq effects on an annual basis from 2025-2035.

Table 7.36. Yearly economic and CO$_2$-eq effects

Model 1	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**Avg.**
Economy	*DKK m (2023 level)*											
Tax of DKK 750 per tonne of CO$_2$-eq[1)]	0	0	925	1,725	2,400	3,000	2,925	2,850	2,750	2,675	2,625	2,000
Peatland[2)]	-1,175	-1,175	-1,175	-1,175	-1,175	-1,175	-1,175	-1,175	0	0	0	-850
Subsidy for afforestation	-275	-350	-450	-550	-675	-750	-850	-925	-975	-1,050	-1,110	-725
Tax on F-gases and other regulations	0	0	75	75	75	75	75	75	75	75	75	50
Total	**-1,450**	**-1,525**	**-625**	**75**	**625**	**1,150**	**975**	**825**	**1,850**	**1,700**	**1,600**	**475**
CO$_2$-eq effects	*m tonnes of CO$_2$-eq*											
Tax of DKK 750 per tonne of CO$_2$-eq	0.1	0.4	1.4	1.8	2.4	2.7	2.8	2.8	2.8	2.8	2.7	2.1
Peatland	0.0	0.0	0.0	0.1	0.2	0.3	0.6	1.0	1.0	1.0	1.0	0.5
Subsidy for afforestation	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.3	0.4	0.6	0.2
Tax on F-gases and other regulations	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	**0.1**	**0.4**	**1.4**	**2.0**	**2.7**	**3.2**	**3.7**	**4.2**	**4.2**	**4.3**	**4.4**	**2.8**

Note: Figures have been rounded to the nearest DKK 25 million.

1) The calculations assume that the CO$_2$-eq tax is phased in gradually from 2027 to 2030.

2) A total of DKK 9.4 bn has been set aside for the rewetting of carbon-rich agricultural land. For calculation purposes, the funds are divided equally between 2025-2032, when the set-aside is expected to be carried out.

Source: Own calculations

Table 7.37. Yearly economic and CO$_2$-eq effects

Model 2a	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	Avg.
Economy	*DKK m (2023 level)*											
Tax of DKK 750 per tonne of CO$_2$-eq with a base deduction of 50 per cent.[1]	0	0	250	775	1,275	1,550	1,500	1,475	1,425	1,400	1,350	1,000
Peatland[2]	-1,175	-1,175	-1,175	-1,175	-1,175	-1,175	-1,175	-1,175	0	0	0	-850
Subsidy for afforestation	-275	-350	-450	-550	-675	-750	-850	-925	-975	-1,050	-1,110	-725
Tax on F-gases and other regulations	0	0	75	75	75	75	75	75	75	75	75	50
Subsidies for biochar by pyrolysis	0	0	-75	-100	-150	-225	-225	-225	-225	-225	-225	-125
Total	**-1,450**	**-1,525**	**-1,375**	**-975**	**-650**	**-525**	**-675**	**-775**	**300**	**200**	**100**	**-650**
CO$_2$-eq effects	*m tonnes of CO$_2$-eq*											
Tax of DKK 750 per tonne of CO$_2$-eq with a base deduction of 50 per cent.	0.1	0.2	1.1	1.4	1.9	2.1	2.2	2.2	2.2	2.2	2.0	1.6
Peatland	0.0	0.0	0.0	0.1	0.2	0.3	0.6	1.0	1.0	1.0	1.0	0.5
Subsidy for afforestation	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.3	0.4	0.6	0.2
Tax on F-gases and other regulations	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Subsidies for biochar by pyrolysis	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.1
Total	**0.1**	**0.2**	**1.2**	**1.7**	**2.3**	**2.8**	**3.3**	**3.8**	**3.8**	**3.9**	**3.9**	**2.4**

Note: Figures have been rounded to the nearest DKK 25 million.

1) The calculations assume that the CO$_2$-eq tax is phased in gradually from 2027 to 2030.

2) A total of DKK 9.4 bn has been set aside for the rewetting of carbon-rich agricultural land. For calculation purposes, the funds are divided equally between 2025-2032, when the set-aside is expected to be carried out.

Source: Own calculations

Table 7.38. Yearly economic and CO_2-eq effects

Model 2b	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	Avg.
Economy	*DKK m (2023 level)*											
Tax of DKK 750 per tonne of CO_2-eq with a base deduction of 50 per cent.[1]	0	0	100	575	1,125	1,375	1,350	1,300	1,275	1,225	1,200	875
Peatland[2]	-1,175	-1,175	-1,175	-1,175	-1,175	-1,175	-1,175	-1,175	0	0	0	-850
Subsidy for afforestation	-275	-350	-450	-550	-675	-750	-850	-925	-975	-1,050	-1,110	-725
Tax on F-gases and other regulations	0	0	75	75	75	75	75	75	75	75	75	50
Subsidies for biochar by pyrolysis	0	0	-75	-100	-150	-225	-225	-225	-225	-225	-225	-125
Total	**-1,450**	**-1,525**	**-1,525**	**-1,175**	**-800**	**-700**	**-825**	**-950**	**150**	**25**	**-50**	**-775**
CO_2-eq effects	*m tonnes of CO_2-eq*											
Tax of DKK 750 per tonne of CO_2-eq with a base deduction of 50 per cent.	0.1	0.3	1.1	1.3	1.7	1.9	2.0	2.0	2.0	2.0	1.9	1.5
Peatland	0.0	0.0	0.0	0.1	0.2	0.3	0.6	1.0	1.0	1.0	1.0	0.5
Subsidy for afforestation	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.3	0.4	0.6	0.2
Tax on F-gases and other regulations	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Subsidies for biochar by pyrolysis	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.1
Total	**0.1**	**0.3**	**1.2**	**1.6**	**2.1**	**2.6**	**3.1**	**3.6**	**3.6**	**3.7**	**3.8**	**2.3**

Note: Figures have been rounded to the nearest DKK 25 million.

1) The calculations assume that the CO_2-eq tax is phased in gradually from 2027 to 2030.

2) A total of DKK 9.4 bn has been set aside for the rewetting of carbon-rich agricultural land. For calculation purposes, the funds are divided equally between 2025-2032, when the set-aside is expected to be carried out.

Source: Own calculations

Table 7.39. Yearly economic and CO_2-eq effects

Model 3a	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**Avg.**
Economy	*DKK m (2023 level)*											
Tax of DKK 250/125 per tonne of CO_2-eq with a base deduction of 50 per cent[1]	0	0	150	500	850	1,050	1,025	1,000	975	950	925	675
Peatland[2]	-1,175	-1,175	-1,175	-1,175	-1,175	-1,175	-1,175	-1,175	0	0	0	-850
Subsidy for afforestation	-275	-350	-450	-550	-675	-750	-850	-925	-975	-1,050	-1,110	-725
Tax on F-gases and other regulations	0	0	75	75	75	75	75	75	75	75	75	50
Subsidies for biochar by pyrolysis	0	0	-375	-500	-775	-1,150	-1,150	-1,150	-1,150	-1,150	-1,150	-775
Total	**-1,450**	**-1,525**	**-1,775**	**-1,650**	**-1,700**	**-1,950**	**-2,075**	**-2,175**	**-1,075**	**-1,175**	**-1,250**	**-1,625**
CO_2-eq effects	*m tonnes of CO_2-eq*											
Tax of DKK 250/125 per tonne of CO_2-eq with a base deduction of 50 per cent.	0.1	0.1	1.0	1.1	1.2	1.3	1.4	1.4	1.4	1.3	1.3	1.1
Peatland	0.0	0.0	0.0	0.1	0.2	0.3	0.6	1.0	1.0	1.0	1.0	0.5
Subsidy for afforestation	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.3	0.4	0.6	0.2
Tax on F-gases and other regulations	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Subsidies for biochar by pyrolysis	0.0	0.0	0.2	0.4	0.5	0.8	0.8	0.8	0.8	0.8	0.8	0.5
Total	**0.1**	**0.1**	**1.2**	**1.7**	**2.0**	**2.6**	**3.1**	**3.6**	**3.6**	**3.6**	**3.8**	**2.3**

Note: Figures have been rounded to the nearest DKK 25 million.

1) The calculations assume that the CO_2-eq tax is phased in gradually from 2027 to 2030.

2) A total of DKK 9.4 bn has been set aside for the rewetting of carbon-rich agricultural land. For calculation purposes, the funds are divided equally between 2025-2032, when the set-aside is expected to be carried out.

Source: Own calculations

Table 7.40. Yearly economic and CO_2-eq effects

Model 3b	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**Avg.**
Economy	*DKK m (2023 level)*											
Tax of DKK 250/125 per tonne of CO_2-eq with a base deduction of 50 per cent1)	0	0	50	325	700	875	850	825	800	775	750	550
Peatland2)	-1,175	-1,175	-1,175	-1,175	-1,175	-1,175	-1,175	-1,175	0	0	0	-850
Subsidy for afforestation	-275	-350	-450	-550	-675	-750	-850	-925	-975	-1,050	-1,110	-725
Tax on F-gases and other regulations	0	0	75	75	75	75	75	75	75	75	75	50
Subsidies for biochar by pyrolysis	0	0	-375	-500	-775	-1,150	-1,150	-1,150	-1,150	-1,150	-1,150	-775
Total	**-1,450**	**-1,525**	**-1,875**	**-1,825**	**-1,850**	**-2,125**	**-2,250**	**-2,350**	**-1,250**	**-1,350**	**-1,435**	**-1750**
CO_2-eq effects	*m tonnes of CO_2-eq*											
Tax of DKK 250/125 per tonne of CO_2-eq with a base deduction of 50 per cent.	0.0	0.2	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	0.9
Peatland	0.0	0.0	0.0	0.1	0.2	0.3	0.6	1.0	1.0	1.0	1.0	0.5
Subsidy for afforestation	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.3	0.4	0.6	0.2
Tax on F-gases and other regulations	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Subsidies for biochar by pyrolysis	0.0	0.0	0.2	0.4	0.5	0.8	0.8	0.8	0.8	0.8	0.8	0.5
Total	**0.0**	**0.2**	**1.2**	**1.6**	**1.9**	**2.4**	**2.8**	**3.3**	**3.3**	**3.4**	**3.6**	**2.2**

Note: Figures have been rounded to the nearest DKK 25 million.

1) The calculations assume that the CO_2-eq tax is phased in gradually from 2027 to 2030.

2) A total of DKK 9.4 bn has been set aside for the rewetting of carbon-rich agricultural land. For calculation purposes, the funds are divided equally between 2025-2032, when the set-aside is expected to be carried out.

Source: Own calculations

Decline in production volume and value for the models

Table 7.41. Change in production volumes and value for the models, 2030 effects

Model	**Effective tax rate in 2030**	**Production value**	**Decrease in production**	**Decrease in production value**
	DKK per tonne of CO_2-eq	*DKK bn*	*per cent*	*per cent*
Model 1/Tax of DKK 750 per tonne of CO_2-eq on fertiliser, liming and livestock				
Crop	750	19.8	7.9	7.6
Cattle	750	16.7	20.2	8.7
Pigs	750	16.7	17.7	13.6
Overall	750	53.2	15.0	9.8
Model 2a/Tax of DKK 750 per tonne of CO_2-eq on fertilisers, liming and livestock, incl. a base deduction of 50 per cent				
Crop	375	19.8	4.8	4.5
Cattle	375	16.7	11.4	4.9
Pigs	375	16.7	11.0	8.4
Overall	375	53.2	8.9	5.8
Model 2b/tax of DKK 750 per tonne of CO_2-eq on liming and livestock, and DKK 750 per tonne of CO_2-eq subsidy for reduced fertiliser, incl. a base deduction of 50 per cent				
Crop	0-375	19.8	0.8	2.6
Cattle	375	16.7	9.8	4.3
Pigs	375	16.7	8.1	6.2
Overall	375	53.2	6.0	4.2
Model 3a/Tax of DKK 750 per tonne of CO_2-eq on fertilisers and liming, DKK 250 per tonne of CO_2-eq on livestock, incl. a base deduction of 50 per cent				
Crop	375	19.8	3.8	2.9
Cattle	125	16.7	6.5	2.8
Pigs	125	16.7	6.6	5.0
Overall	125-375	53.2	5.6	3.5
Model 3b/Tax of DKK 750 per tonne of CO_2-eq on liming, DKK 250 per tonne of CO_2-eq on livestock, and DKK 750 per tonne of CO_2-eq subsidy for reduced fertiliser, incl. a base deduction of 50 per cent				
Crop	0-375	19.8	0.0	1.1
Cattle	125	16.7	4.7	2.1
Pigs	125	16.7	3.4	2.6
Overall	125-375	53.2	2.6	1.9

Note: Production value is stated for 2030, includes intra-agricultural deliveries and is calculated at the 2023 level. It should be noted that for crop producers in the b variants, a range of 0-375 is specified, as there is still a tax on liming even though there is no tax on applied fertiliser.
Source: Own calculations

Table 7.42. Degree of price pass-through in the models, per cent

	Tax rate in 2030		Partial models			Overall
	Livestock (base deduction, per cent)	Fertiliser (base deduction, per cent)	**Crop**	**Cattle**	**Pigs**	**Overall**
	DKK per tonne of CO_2-eq		*Per cent (pass-through in consumer prices)*			
Model 1	750 (0)	750 (0)	38	62	45	56
Model 2a	750 (50)	750 (50)	39	58	46	51
Model 2b	750 (50)	750 (subsidy)	-	55	38	49
Model 3a	250 (50) / 125 (0)	750 (50)	39	56	42	46
Model 3b	250 (50) / 125 (0)	750 (subsidy)	-	50	26	41

Note: Partial models are calculated with the same rates as the general models, but where the 3 agricultural branches are taxed separately.
Source: Own calculations.