Analysis method for welfare economic costs of mitigation measures in the Climate Policy Plan

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This Annex describes the most important methodological considerations regarding the analyses of potential mitigation measures for use in the Climate Policy Plan.

In general terms, the method applied is that recommended by the Ministry of Finance.

Mitigation measures to reduce greenhouse gas emissions

A mitigation measure consists either of a policy implementation instrument exclusively, or of a technical measure and an associated policy implementation instrument.

The analyses are based on the understanding that a mitigation measure is either:

1. a policy implementation instrument alone (in the form of legislation, taxation, subsidy scheme), which contributes directly to regulating the market.

2. a combination of a technical measure leading to CO_2 reduction and a policy implementation instrument affecting behaviour (in the following referred to as a behavioural instrument). A mitigation measure can therefore consist of an afforestation project as the technical means, while the policy implementation instrument, such as a subsidy, creates the incentive to plant the forest.

A welfare economic CO_2 shadow price is calculated for each mitigation measure, based on the welfare economic costs and the reduction in greenhouse gas emissions, specified as DKK per tonne CO_2 equivalent reduced.

Re 1) When implementing only a policy implementation instrument, e.g. a tax, it is up to consumers/enterprises to decide which technical measure to use. Therefore, it is only relevant to assess the welfare economic effects of the policy instrument. This approach is applied if there is no specific focus on *how* the carbon reduction will be achieved.

Re 2) When focussing on the implementation of a specific technical measure the technical measure as well as the policy implementation instrument must be included in the welfare economic assessment of the mitigation measure. This also applies when calculating the cost-effectiveness of the measure. The reason is that the technical measure can be implemented using several policy implementation instruments which give rise to various degrees of welfare economic costs or benefits (e.g. in the form of administrative or distortionary losses). The policy implementation instrument is chosen on the basis of a review of the barriers considered to exist in the field.

Reference

All changes are assessed relative to a baseline showing the conditions in the absence of a mitigation measure. The baseline reflects the status quo. Therefore, it does not take account of possible changes in demand and supply as a consequence of future policy decisions.

The reference point is the Danish Energy Agency's baseline projections (autumn 2012), including subsequent amendments, see box page x of the Climate Policy Plan. This baseline scenario includes the Ministry of Transport's transport projection 2012 and, in the case of agriculture, the Danish Centre for Environment and Energy's projection of greenhouse gas emissions 2012.

It is assumed that measures stipulated by the Green Growth agreement are incorporated in the baseline scenario (e.g. biomass degassing), apart from the effects, however, of measures not yet implemented in relation to the nitrogen reduction of 10,000 tonnes N per year.

Method for calculating the welfare economic shadow price of greenhouse gas reductions

Using present values is the relevant approach to assessing the welfare economic costs of greenhouse gas mitigation measures. The present value expresses the discounted value of benefits and costs of a given measure.

With r expressing the discount rate and T the time horizon, the net present value of the measure NPV can be calculated as follows:

$$NPV = \sum_{t=1}^{T} \frac{B_t - C_t}{(1+r)^t} - \sum_{t=1}^{T} \frac{\Delta CO_2^t \cdot P^{CO_2}}{(1+r)^t}$$

B_t and C_t reflect the benefits and costs, respectively, of the measure in the period t. ΔCO^t_2 indicates the change in emissions of greenhouse gasses as a consequence of the measure in the period t. This figure is negative if emissions are reduced. r is the discount rate. P^{CO2} describes the damage costs of CO_2 emissions.

The global damage costs of climate change, P^{CO2}, are very difficult to determine. Since absolute and binding targets have been set for greenhouse gasses, the welfare economic costs can be expressed as mitigation costs per unit of CO_2 equivalent (the CO_2 shadow price).

Shadow price

The unit cost of reducing greenhouse gas emissions (the CO_2 shadow price) can be calculated for a specific measure by setting the present value equal to zero in the formula above. The cost is found by isolating the price of the CO_2-equivalent reduction, assuming this is constant over time:

$$NPV = \sum_{t=1}^{T} \frac{B_t - C_t}{(1+r)^t} - \sum_{t=1}^{T} \frac{\Delta CO_2^t \cdot P^{CO_2}}{(1+r)^t} = 0 \Rightarrow$$

$$P^{CO_2} = \sum_{t=1}^{T} \frac{B_t - C_t}{(1+r)^t} \cdot \left(\sum_{t=1}^{T} \frac{\Delta CO_2^t}{(1+r)^t} \right)^{-1}$$

To be able to calculate the unit costs of the relevant mitigation measure, the following entities will have to be determined:

- The discount factor
- The effect on emissions of greenhouse gasses
- The economic costs and an assessment of who bears these costs
- The welfare economic direct costs and distortions, C

- Welfare economic consequences of any positive or negative ancillary effects in addition to the CO_2 reduction, *B*.

To the extent possible benefits and costs are assigned to the annual time periods within which they actually occur. This can be of significance because future effects are discounted. The parameters are inserted into the formula and the unit price of a CO_2-equivalent reduction can be determined.

The following sections describe the parameters in more detail:

The discount factor - r and the time aspect T

Following the recommendations of the Ministry of Finance, a common social discount rate of 4.00 % is applied.

The present value is calculated for the 30-year period from 2013 to 2042. A 30-year period has been chosen because the time horizon should be long enough to allow all significant benefits and costs of the mitigation measure to be included and described, including the technical lifespan of fixed asset investments and the reduction of greenhouse gasses after 2020. For measures to mutually be comparable, it is important that they are discounted over the same period of time.

The analyses are conducted at 2012 prices.

The change in carbon emissions – ΔCO^t_2

The term ΔCO^t_2 describes the annual change in greenhouse gas emissions caused by the mitigation measure relative to the sector-specific baseline projection. The reduction is specified per year, because, due to discounting, future reductions do not carry the same weight as present reductions.

The new emissions factors and Global Warming Potentials (GWPs) from the 2006/2007 IPCC guidelines are applied.

The reduction in other greenhouse gasses than CO_2 (such as methane and nitrous oxide) is expressed in CO_2 equivalents. Conversion to CO_2 equivalents is performed by multiplying the CH_3 emissions (methane) by 25 and the N_2O emissions (nitrous oxide) by 298 (source DCE).

ETS and non-ETS sector

The national 40 % target does not distinguish between the ETS and the non-ETS sector. Mitigation measures both inside and outside the ETS sector are analysed; i.e. a CO_2 shadow price is *also* calculated for the ETS sector. Similarly, some mitigation measures will have effects in both the ETS sector and the non-ETS sector (e.g. heat pumps in households).

In the analysis of the CO_2 shadow price for use in the Climate Policy Plan, the total volume of CO_2 must be included (the denominator in the shadow price), i.e. both the ETS and the non-ETS CO_2 reduction.

This is a deviation from previous analyses, which calculated a CO_2 shadow price in relation to a target specified for the non-ETS sector *alone,* and which therefore did not include CO_2 reductions in the ETS sector. Instead, CO_2 reductions in the ETS sector were included as a co-benefit valued at the CO_2 allowance price (in the same way as with other co-benefits such as reduced nitrogen leaching).

In the analyses of the 40 % reduction target stipulated by the Climate Policy Plan, the value of CO_2 allowances not to be included in the welfare economic net costs (i.e. the numerator in the shadow price fraction).

The electricity price includes the value of the CO_2 allowances. This should be considered in the analysis, which should therefore not include the allowance value. Thus, the electricity calculations must be net of the value of CO_2 allowances. This value is calculated as the amount of CO_2 from electricity generation multiplied by the CO_2 allowance price. The CO_2 emission factor for electricity is published in the Danish Energy Agency's document "*Forudsætninger for samfundsøkonomiske analyser*" from April 2011 or later versions. When calculating figures for offshore wind turbines, the net costs are included in the numerator, i.e. investments, operating costs etc. minus the value of the displaced electricity production. To this is added the value of the allowances, calculated as the allowance price multiplied by CO_2 emissions from the displaced electricity production (to offset the fact that the allowance value is included in the electricity price). The displaced volume of CO_2 is included in the denominator for the shadow price.

On the other hand, in the economic analysis, the value of the allowances must be included for the relevant stakeholder. Therefore, the electricity price (which includes the value of the allowances) can be used for this analysis.

CO_2 from electricity

When it comes to emission factors for the assessment of the effects of electricity production, choosing the correct method is not easy. In the short term, increased electricity production from e.g. wind turbines will probably displace output from existing capacity (in Denmark or abroad). The effect on CO_2 emissions will therefore be determined by the marginal electricity production (also in relation to the effect on capacity abroad, because in the context of the Climate Policy Plan, emissions are adjusted for trade in electricity). It is the emissions from marginal electricity generation that have been used as the basis for electricity trade adjustments in the baseline projection used in the Climate Policy Plan. Consequently, the baseline projection is used extensively when assessing this mitigation measure. In the longer term, however, additional wind power capacity will mean a change in the demand for new capacity. Due to the government's target of fossil free electricity generation in 2035, it must be assumed that, to a very great extent, new capacity will have to be fossil free. This means that the effect of the additional wind power capacity on emissions of CO_2 will be very small in the long term. In other words, the government's target means that a considerable number of additional wind turbines will have to be established before 2035; it is merely a matter of expediting the investment. When comparing with the average electricity that is currently included in the assumptions, the consequence is that additional wind power capacity has a higher CO_2 emissions effect in the short term and a lower effect in the long term.

Against this background, it was decided to use the emissions factors from marginal electricity generation up to 2025. After 2025, it is expected that the existing fossil capacity will be gradually phased out. Concurrently, low emissions factors are gradually applied for the long-term marginal electricity production.

Assumptions about CO_2 reduction for measures related to bioenergy and livestock manure etc.

For energy willow, the analysis should not include an increase in CO_2 displacement due to a larger production of willow chips in Denmark, even if it is assumed that the willow chips produced are used in the Danish CHP sector. The reason for this is that Danish CHP plants are free to choose between wood chips etc. from Danish producers as well as imports when meeting the requirement for a certain share of renewables in their production. Furthermore, an increase in the Danish production of willow chips is not expected to result in (considerably) lower prices of chips. Willow chips are traded at par with wood chips in the CHP sector. As wood chips (and wood pellets) are imported from a number of counties, it must be assumed that the prices in foreign trade determine the price of wood chips in Denmark and thus also the price of willow chips. Changes in Danish production of willow and wood chips are therefore not assumed to have an effect on the total consumption of chips in the Danish CHP sector. Accordingly, the welfare economic analyses should not include displacement of fossil fuels in the CHP sector. The greenhouse gas effect of energy willow therefore originates solely from nitrogen usage and nitrogen losses, which have an effect on emissions of nitrous oxide, fuel consumption and carbon sequestration in the soil. This corresponds to the assumptions in IFRO report no. 205, Economic Efficiency Assessment of Climate Measures for Agriculture, 2010.

When straw is used for fuel in the CHP sector, the effects differ from those of energy willow. The reason is that transport costs are significantly higher for straw than for wood chips. This does not prevent trading between regions and across national borders. However, local usage has a considerable advantage in terms of lower transport costs. Straw is therefore not an internationally traded commodity in the same way as willow chips. The straw used in the CHP sector is therefore assumed to originate from Danish suppliers. Furthermore, it is assumed that the demand for straw for fuel in the CHP sector will be determined primarily by policy requirements, and that requirements for an increase in the use of straw in the CHP sector will be linked to a requirement for a corresponding increase in the use of biomass in this sector. Based on this, it is assumed that the increased use of straw will displace natural gas in the CHP sector. This effect will be reduced, and possibly eliminated, if the CHP plants are free to choose between straw and other types of biomass such as wood chips when meeting a requirement for a certain share of renewables in their production. In general, the analyses for agriculture assume that there is not a free choice of fuel, and an independent analyse is performed for the measure free choice of fuel.

For the mitigation measure livestock manure for biogas, it is assumed that an increase in biogas production fully reduces the use of fossil fuels in the CHP sector. The reason for this assumption is that biogas is a voluminous commodity, which it is uneconomic to transport across large distances (unless it becomes possible to distribute biogas via the natural gas grid). An increase in the production of biogas will therefore have to be accompanied by a corresponding increase in the consumption of biogas in CHP production. Promotion of the use of livestock manure in biogas production is therefore assumed to displace fossil energy. This also corresponds to the assumptions in IFRO report no. 205.

For plant matter and other residual product used as feedstock the same assumptions apply as for the use of livestock manure in biogas production, i.e. these measures are assumed to reduce the use of fossil fuels, in the form of natural gas, in the CHP sector.

Bioethanol is an internationally traded energy product with low transportation and storage costs relative to its value. Therefore, it makes no real economic difference whether or not this product is produced in Denmark. Accordingly, it cannot be expected that establishment of a bioethanol production in Denmark will have any significant effect on the price or the consumption of this product. Bioethanol produced in Denmark will merely replace imported biofuels. It is therefore assumed that there is no CO_2 effect from an increase in the use of straw for bioethanol production in Denmark.

Economic expenses

Economic costs are calculated for each of the relevant stakeholders, including the financial consequences for the state. Relevant stakeholders include households, agriculture, the state, local government, industry, etc. The economic costs form the basis for the assessment of welfare economic costs, C, dealt with in the next section.

The economic costs are also shown, namely the direct additional costs to the state, households and business (incorporating for example industry, trade and service sectors, agriculture, the energy sector etc.). The economic costs are determined as annual costs evenly distributed over the 30-year period from 2013-2042, i.e. as an annuity in DKK million per year.

Costs, including distortionary effects - C

The analyses should incorporate the net costs of the considered mitigation measure (calculated as the change relative to the baseline), as well as costs of administration or similar associated with the introduction of the measure.

Part of the economic consequences of the measures are due to distortions of consumer choices. The analyses should therefore take account of these distortions as far as possible. For this purpose, the analyses apply a standard conversion factor. They also incorporate estimates of the deadweight loss triangle (in the following referred to as triangular loss) associated with commodity taxation and labour supply distortions as a result of taxation, see annex 1 for details.

The distortion of labour supply (tax distortions) is calculated as 10 %, if the distortion affects everyone (i.e. both people in and out of work), and as 20 % if only people in work are affected. The Ministry of Finance will account for these assumptions in more detail in the upcoming new guidelines.

The energy prices applied are from the Danish Energy Agency's baseline projection published in September 2012. Projections of real prices in the period up to 2035 are applied. After 2035, constant real prices are assumed.

Prices related to transport are from the analysis of transport unit costs conducted by the Technological University of Denmark, see the most recent version of the document "*Transportøkonomiske enhedspriser*" (transport economic unit costs) at http://www.modelcenter.transport.dtu.dk/Publikationer/Transportoekonomiske-Enhedspriser.

For agricultural commodity prices the same approach is applied as in IFRO report no. 205, Economic Efficiency Assessment of Climate Measures for Agriculture 2010. Projections of prices in the EU and Denmark have been made using the AGMEMOD model, the world market price assumptions of which are based on projections by the American Food and Agricultural Policy Research Institute (FAPRI, 2009). IFRO's updated AGMEMOD price projections from 2012 are used. These projections comprise the development in real prices for agricultural products in Denmark up to 2020. After 2020, constant real prices are assumed.

Treatment of the costs of barriers

This section addresses situations where win-win measures advantageous also from a business perspective are not adopted without the use of a policy implementation instrument.

It is difficult to estimate the 'correct' shadow price for win-win measures that are financially advantageous and should therefore be adopted even without the use of a policy implementation instrument.*

In these situations, there are barriers which prevent the measure from being implemented by itself.

Barriers should be divided into two categories. Barriers can be in the form of inconveniences, such as having to dig up your garden, having to employ workmen, etc.; i.e. barriers which entail actual costs; known as genuine transaction costs. The other type of barrier is lack of information or coordination etc. which leads to citizens/businesses failing to respond to price signals, which a rational and fully informed agent would have responded to. These are also barrier related costs, but they do not represent the actual costs of dealing with the barrier.

As a rule, the genuine transaction costs should be determined and included in the welfare economic analysis. If the genuine transaction costs cannot be estimated, they can be stipulated as a share of the economic surplus; a share, however, which is not immediately known. This expresses the costs that should be included as a minimum. However, this will cause distortions in relation to analyses of measures with financial losses, which presumably also have barrier costs that cannot be determined.

With regard to information barriers, it may be argued that the barriers can only be removed by introducing policy instruments (e.g. standards, regulation, etc.), and that the barrier costs should not be included in such cases. Information barriers could be lack of knowledge and awareness, lack of confidence in the market or lack of coordination. In such cases, a policy instrument may be exactly what is needed to overcome the barrier, and therefore the barrier costs are eliminated by the instrument. In other words, the policy instrument provides a benefit that corresponds to the barrier costs. In certain situations, the barrier costs may be high for the individual agent but relatively cheap for the state to overcome by e.g. introducing standards, legislation, information.

It can be very difficult to divide a barrier into what is caused by actual transaction costs and what is caused by information barriers. In many cases, a specific barrier can be a combination of both of these.

For the tax instrument, barrier costs are already implicitly included in the analysis via the demand curve, as an optimal allocation is assumed. For measures with policy instruments such as requirements, standards, information and guidelines, the barrier costs are managed by the instrument. For the measure involving subsidies for heat pumps/district heating, the barrier can be lack of information, lack of confidence in the market, or unwillingness to have one's garden dug up, to endure noise, and to spend time on workmen etc. An attempt has been made to determine the genuine transaction costs for this measure, and these costs have therefore been included in the analysis of the shadow prices.

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* In principle, the challenge related to calculating a 'correct' shadow price will also apply where the technical costs of a specific measure shows a an economic loss.

Benefits - B

The benefits of the mitigation measure pertaining to direct effects in the form of reduced greenhouse gas emissions are included in the figure for CO2-equivalent reduction. In the formula, *B* expresses possible *other benefits*.

These can be environmental co-benefits, including reduced emissions of nitrogen, SO_2, NO_X and particles, as well as improved biodiversity. There may also be traffic-related co-benefits such as less nuisance from noise, less congestion, or health-related co-benefits such as fewer ill people, fewer traffic injuries and fewer deaths. The most important environmental co-benefits of the relevant agriculture measures include reduced nitrogen load on the aquatic environment, reduced odour nuisance, lower pesticide consumption and greater biodiversity.

Where robust results for the value of co-benefits exist, these have been valued in the analysis.

Several mitigation measures have a positive derived effect on Denmark's international target for renewable energy and/or energy savings targets. However, these co-benefits cannot be valued and have therefore been highlighted quantitatively in assessment of the mitigation measures.

For prices of derived co-benefits, the guidelines in box 1 are used in accordance with the recommendations from the Ministry of Finance.

Box 1: Guidelines for prices of derived co-benefits

If there is a binding target for the substances in question, the highest of the following two prices should be chosen.

- The marginal reduction costs in Denmark of achieving the binding target.
- Damage costs for Danish citizens

If there is no binding target, the damage cost for Danish citizens should be applied.

If the binding target has been more than met, the damage cost for Danish citizens should be applied.

The price above for emissions is multiplied by the figure for total emissions, i.e. both the percentage share of emissions with an effect in Denmark and the percentage share of emissions with an effect abroad. The national delimitation is therefore reflected in the pricing of the emissions.

The value of effects abroad must be stated separately, however, as a general rule, they should not be included in the shadow price in the central estimate.

The following accounts for the prices of derived effects.

There are binding targets for NOx, SO2, phosphorus, nitrogen and ammonia. For particles, there is a binding target relating to air quality in cities, while the binding target under the Gothenburg Protocol will first take effect in a couple of years.

For ammonia (NH3), a marginal reduction cost of DKK 55/kg N (stated in welfare-economic 2012 prices) is used. The source is IFRO.

For nitrogen (N), a marginal reduction cost of DKK 54/kg N calculated in connection with work carried out by the Nitrogen Committee is used. The price has been calculated in terms of welfare economic costs and is stated at 2012 prices. The source is IFRO. There are no up-to-date calculations of the marginal reduction cost for NOx. Therefore, a tax rate of DKK 25/kg NOx (2012 prices) is used instead. If calculated in terms of welfare-economic costs (i.e. raised by the net-tax factor), the price ends at DKK 33 /kg NOx. The tax rate expresses the highest cost at which a reduction measure will be carried through. Reduction measures that are more expensive than the tax rate will not be implemented, because it will be more economical to pay the tax.

No calculations are currently available for the marginal reduction costs for particles (PM2.5). The Ministry of the Environment plans to launch a project on this, however the result of this project will not be available in time to be included in this analysis. It is therefore recommended to use the national damage cost. For point sources, the price has been calculated at DKK 11/kg and DKK 36/kg PM2.5 for rural and urban areas, respectively, (stated in welfare-economic 2012 prices), see annex 2.

For SO2, the target has been more than met, and the national damage cost is applied. For point sources, the price has been calculated at DKK 5/kg and DKK 26/kg SO2 for rural and urban areas, respectively, (welfare-economic 2012 prices), see annex 2.

For transport, the Ministry of Transport's catalogue of key figures is used. Adjustments are made in accordance with the guidelines above (box 1) for prices of derived co-benefits, including a separate calculation of effects abroad.

In some cases, the value of the co-benefits may dominate the valued benefit of the actual CO_2 reduction, so that carbon reduction cannot be said to be the primary effect of the relevant mitigation measure. Furthermore, the calculation of co-benefits can be associated with considerable uncertainty about consequences and valuation and it may therefore be incomplete. Uncertainty in the individual calculation varies significantly, and the uncertainties limit the possibility for consistency across sectors and mitigation measures. For co-benefits, uncertainties can be reduced by looking at the shadow price without co-benefits, however information about primarily derived environmental and health effects will then be lost. A shadow price without the value of co-benefits is also calculated.

Other assumptions

Net-tax factor

A net-tax factor of 1.325 is used in accordance with recommendations from the Ministry of Finance.

Economic rent

For the measures that lead to land-use changes on arable land, the financial costs are calculated as changes in economic rent. Economic rent represents the net return to the factor of production 'arable land'. It is calculated as the difference between the (sales) value of crops and the total costs of cultivation, including seeds/sowing, fertiliser, chemicals, payroll costs (including owner's pay), as well as depreciation and interest on machinery and equipment. In principle, economic rent corresponds to the rent that can be charged for land with a given cultivation value.

In the publication, "*Budgetkalkuler fra Dansk Landbrugsrådgivning*" (budget calculations from the Danish agricultural advisory company DLBR), economic rent has been calculated as 'contribution margin after deduction of machinery and labour costs' for various crops. Changes in income are therefore based on changes in the contribution margin after deduction of machinery and labour costs, where both variable costs and capacity costs are paid. For the period 2013-2020, price projections from the AGMEMOD model have been used for the relevant crops as described above. After 2020, constant prices in real terms are assumed.

The economic rent for some agricultural production has so far been negative in the budget calculations from DLBR. IFRO report no. 205, Economic Efficiency Assessment of Climate Measures for Agriculture 2010, discusses and provides a possible explanation for these negative figures. However, recent years' increases in the prices of crops have meant that there are no longer negative figures for contribution margin II for the most common crops. Similarly, there has been an economic improvement for milk and pig productions, so that positive net profits are now also being seen for these after deduction of capital and labour. The earnings of the various branches of production are heavily influenced by the large fluctuations in both sales prices and input prices. Rising prices on crops, for instance, will improve the earnings of plant producers. However, they will also lead to an increase in the cost of feed, and this will reduce the earnings of livestock producers in the short term.

If the economic rent is negative, in general, it is recommended to use the method used in IFRO report no. 205, i.e. to set economic rent to zero. Note, however, that IFRO will make a decision about the interest rate in the individual calculation of the specific mitigation measures. Note also, that the new projections with AGMEMOD have revealed that the issue of negative contribution margins is no longer topical.

Derived economic effects

Derived economic activity effects in connection with the implementation of mitigation measures are not included (e.g. reduced employment). In this respect, the analysis follows the principles set out in the guidelines from the Ministry of Finance. If a specific employment effect of an measure is known, this effect may very well be mentioned in connection with the measure, however the employment effect should not be valued and included in the calculations.

Subsidies

The welfare-economic analysis and the economic analysis differ in the way they deal with production and environmental subsidies. The economic analyses include all subsidies as contributions to the total earnings of the farms. The welfare-economic analyses leave out state subsidisation, because it merely constitutes transferals between different groups within Danish society. EU subsidisation, on the other hand, constitutes an added gain for Denmark. The marginal effect of the subsidies received on Denmark's payments to the EU is near to naught. EU-funded subsidies are therefore included in full in the welfare-economic calculations.

Sensitivity analyses

The sensitivity calculation in the welfare economic analysis tests the robustness of the results against large or small changes in important uncertain assumptions.

The following sensitivity calculations should be performed:

- discount rates of respectively 3% and 6%;
- higher and lower energy prices;
- higher and lower prices of important derived effects such as nitrogen, NOx, etc.

Finally, break-even analyses may be carried out, which examine the tipping-point of results, i.e. the point at which a result changes from a welfare economic loss to a welfare economic gain. This will provide information about what the value of the non-valued parameters (e.g. biodiversity) must be in order to change the result.

Overview of assumptions

	Assumption applied	Source
Important assumptions		
Discount rate	4.00%	Danish Ministry of Finance
Net-tax factor	1.325	Danish Ministry of Finance
Price level	2012 prices	
Time period for shadow price	30-year period (2013-2042); discounted to 2013	
Prices		
CO2 allowance price		Danish Energy Agency baseline projection, September 2012
Fuel prices		Danish Energy Agency baseline projection, September 2012
Prices of agricultural products		AGMEMOD model
Prices of transport		Transport economic unit costs, July 2010
Price of nitrogen losses to the aquatic environment (welfare-economic calculation)	DKK 54 per kg N	IFRO
Price of SO2 (welfare-economic calculation)	For point sources (stationary installations) DKK 5/kg for rural; DKK 26/kg for urban	Danish Ministry of the Environment
Price of NOx (welfare-economic calculation)	DKK 34/kg	Danish Ministry of the Environment
Price of PM2.5 (welfare-economic calculation)	For point sources (stationary installations) DKK 11/kg for rural; DKK 36/kg for urban	Danish Ministry of the Environment
Price of ammonia losses (NH3) (welfare-economic calculation)	DKK 55 per. kg N	IFRO
Distortions in the supply of labour	20% for changes in taxation (e.g. residual tax) However, 10% if influence on the relative prices	Danish Ministry of Finance
Projection		

Energy	Danish Energy Agency's baseline projection, September 2010, including subsequent amendments	
Agriculture	AGMEMOD model	
Transport	Danish Ministry of Transport's projection 2012	

Annex 1 Distortionary effects

Calculation of the distortionary effects of policy instruments

The behavioural instrument chosen will distort consumer choices, depending on the nature of the instrument and on who pays the costs of the instrument, *see box 2*. The methods are described in more detail below.

Box 2: Adjustments when calculating costs on the basis of various types of behavioural instrument	
Behavioural instrument:	Calculation of costs and distortionary effects
Public expenditure (e.g. investments or subsidies)	Calculated in market prices and increased by the distortionary cost (20%). Factor prices are adjusted by a net-tax factor of 1.325.
Changes in state revenue from taxation	Only 20% of the revenue loss from the direct market is included in the welfare economic calculation, corresponding to the distortionary cost. The revenue loss on the derived market and the triangular loss (the deadweight loss in the goods market) also affect the supply of labour decision and are included with the distortionary cost of 20%. Furthermore, the revenue loss on the derived market and the distortionary cost are included in full in the welfare economic analyses, corresponding to the burden on the individual citizen. Overall, the various elements are included at 120% in the analysis.
Private expenditure (and revenues)	Calculated in market prices. Factor prices are adjusted by the net-tax factor of 1.325.
Excise taxes	The deadweight loss on the goods market is calculated. In the case of an increase in an existing tax, the deadweight loss first consists of the triangular loss (from the existing situation to the new situation). Second, to this figure is added the change in the tax base due to the tax increase (from the situation with the existing tax to the situation with the new tax) multiplied by the existing tax rate (i.e. tax rate before the proposed increase). The total deadweight loss on the goods market is increased by 20% to take account of the distortionary effect on the supply of labour.
Establishment of standards and information campaigns	In the case of the introduction of standards, the distortionary effect should also be calculated because the behaviour of consumers and businesses is affected in the opposite direction of what is economically optimal. As a general rule, distortionary effects because of changes in consumer behaviour have been calculated in market prices. Distortionary effects on the decisions of private businesses are adjusted by the net-tax factor of 1.325 in order to convert the value to market prices. The distortionary effect is increased by the distortionary cost of 20% in order to take account of the effect on the supply of labour. If it can be argued that the regulation merely ensures the elimination of information barriers or similar, the distortionary effect should be left out of the calculation, because such cases are only about consumers choosing the

	optimal bundle of goods in the absence of the information barriers that existed previously.

The following describes the distortionary effect in the goods and labour markets as a consequence of tax funding, excise taxes and direct regulation.

It should be noted that the rate for distortions in the supply of labour has been changed, as mentioned previously.

Distortions in the supply of labour occur either through changes in prices or through changes in tax rates. Both of these situations can affect disposable earnings and, thus, the supply of labour.

If the **price level** changes, both people in and out of work will be affected. For people out of work, there will obviously be no distortionary effect on the supply of labour. However, for people in work, increases in prices, for example, will mean a reduction in their real earnings, and they will therefore work less. The total effect on the supply of labour is calculated as 10% of the price increase including the net-tax factor. Changes in the price level can occur as a consequence of changes in tax rates, user fees and administrative measures such as standards.

If there is a change in the **tax burden**, this will alone affect people in work. Increased taxes will mean lower disposable earnings and less incentive to work. The distortionary cost is determined at 20% of the tax funding requirement, including the net-tax factor. Changes in the tax burden can occur by using a residual tax such as a basic tax rate.

What is new about this approach is that calculations for administrative measures or measures to introduce user fees now also have to include a distortionary effect on the supply of labour. Administrative measures or measures to introduce user fees do not necessarily have consequences for the state budget, however, these measures *do* affect the supply of labour, as they cause rising prices. Furthermore, user fees can be more distortionary than tax funding, because user fees also create distortions in the goods market.

Distortions in the supply of labour due to the financial consequences of the policy instrument for the state

Welfare economic analyses usually assume a budgetary equilibrium for public finances. Mitigation measures that are an overall burden on public finances can either be funded through increased taxes or through lower expenditure. The compensating change in the basic tax rate gives rise to a tax distortion as the distortionary effect of the basic tax rate on the supply of labour changes. The supply of labour depends on the marginal real disposable income, and this figure represents the additional consumption, i.e. the additional purchasing power, which the individual worker can achieve if he offers himself for an additional hour of labour. The increase in the basic tax rate reduces the volume of consumer goods which the consumer can buy with his income. When the benefit of working is reduced, the supply of labour will fall.

The effect on the supply of labour is occasioned by two effects: the income and substitution effects. The income effect encourages the individual to work more in order for his real income to cover the same consumption possibility as before the tax raise. The substitution effect encourages the individual to work less because the benefit of working has been reduced (which is the same as saying that it has become relatively less expensive to take time off from work).

If expenditure is funded through the elimination of other expenditure, it means the benefits associated with this expenditure will also be eliminated.

The change in the revenue for the state is estimated on the basis of net present value (NPV) of the stream of income and expenditure for the state. The benefits and drawbacks that have no financial consequences for the state are therefore not included in this calculation. For example, in this context, the valued benefits of time saved, and of reductions in atmospheric pollution and in the number of accidents, will not have to be included in the calculations.

The distortionary cost is calculated by adjusting the tax funding requirement by the social marginal cost of tax funding, which has been determined at 20%, while assuming that a basic tax rate is used as a residual policy instrument and that the rate is changed by a corresponding amount. The calculated tax distortion is then included as a cost in the overall assessment, i.e. in C in the formula above.

The costs of tax funding can have a huge significance for the result of the welfare economic assessment. If one assumes, for example, that an instrument requires tax funding of DKK 100 million, and that the marginal costs for society of raising distortionary taxes are DKK 0.20 for each DKK collected in tax, and if account is taken of the distortion costs of tax funding, the relevant project cost will not be DKK 100 million but rather DKK 120 million.

The funding requirement for the state also has to be adjusted by the net-tax factor in order to fully reflect the reduced consumption possibilities, *see above*. The net-tax factor of 32.5% in the calculation reflects that public expenditure of DKK 100 million funded through taxes requires collecting DKK 132.5 million. Then the distortionary cost is calculated by multiplying the taxation need, including the net-tax factor, by the societal marginal taxation cost of 20%. In this example, the taxation cost is thus calculated on the basis of the total collection need of DKK 132.5 million, which results in a distortionary cost of DKK 26.5 million. The calculated distortionary cost is then included as a cost in the overall assessment.

The distortionary cost/triangular loss of excise taxes in the goods market

It is assumed, as a starting point, that households (businesses) have designed their consumption (the relationship between the factors of their production) so that their welfare is maximised within their budget constraint (their costs are minimised within the boundaries of their production). In the market equilibrium, without market-based regulation in the form of taxes etc., a (personal financial) optimal level of consumption (production) is achieved. For the last unit purchased, the benefit, in the form of extra welfare for households, therefore equals the price of the good, and, similarly, for the last unit of the good sold for the business, the marginal costs will equal the sales price.

Excise taxes affect the relative price relationship between taxed goods and other goods, and occasion a difference in the price paid by the buyer (the price inclusive of tax) and the price obtained by the seller (the price exclusive of tax). As a result of the increased price of the taxed good, the consumer will substitute the taxed good with other goods. Thus taxes distort consumption patterns away from the market equilibrium and give a net loss for society (triangular loss). The size of the triangular loss depends e.g. on the sensitivity of the consumption pattern to changes in the price of the good in question; i.e. the own-price elasticity of the good.

This situation is illustrated in figure 1 below in which MC represents the price without taxes, MCMC+ τ^1 represents the price with taxes imposed, and MC+ τ^1+τ^2 represents the price with an increase in the already imposed tax.

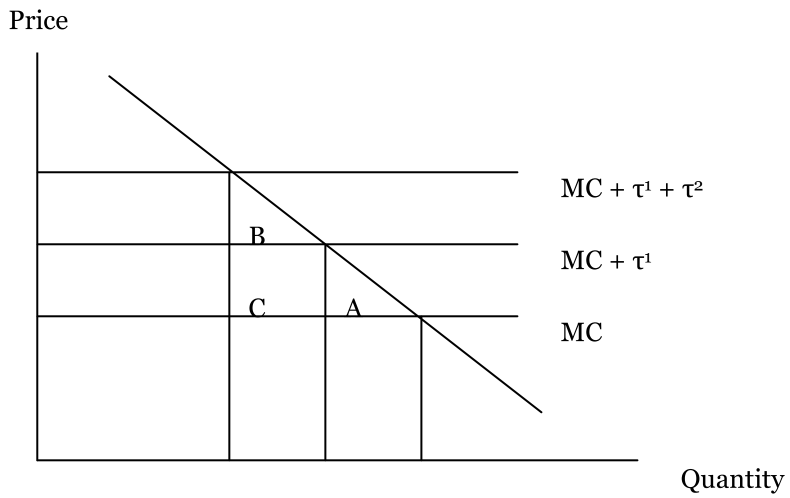


Figure 1 Illustration of distortionary effects in the goods market from an excise tax

The triangular loss, which relates to the directly distortionary effect from the tax, has been included in the welfare-economic calculations:

- *Introduction of a new tax:* The loss is calculated as ½ * tax rate * change in quantity (the triangular loss). The change in quantity is the expected change to the tax base caused by the tax (A in figure 1).

- *An increase in an existing tax:* The loss is calculated from the existing situation to the new situation (½ * tax raise * change in quantity). To this is added the loss of welfare economic surplus on existing consumption (the reduced tax base * the old tax rate). Before the tax raise, the distortionary cost of the tax is constituted by triangle A. After the tax raise the distortionary cost is constituted by A + B (the triangular loss) + C (lost tax revenue due to reduced consumption). The calculation of the welfare economic consequences of the tax raise includes the increase in the triangular loss corresponding to B + C.

The distortionary cost/triangular loss of excise taxes when other markets are affected

Based on a significance criteria, it has been assessed whether the excise tax has a significant derived effect on other markets. In practice, other markets are examined in which changes will have significant financial consequences for the state (e.g. changes in demand for a good which is taxed very differently than the average good).

Situations like this occur when there are complementary goods which are being demanded in more or less fixed quantity ratios, such as cars and fuel. It follows from this that a tax on motor fuel (market 1) will also affect the demand for cars (market 2). In other words, there is a tax revenue change in market 2. In the example given, the loss of revenue from taxes on the sale of cars will be included as a triangular loss with the full value (as C in the figure).

In addition to affiliated markets, it will also be relevant to look at the effect on the labour market.

Losses in supply of labour

In addition to the triangular loss from distortions in consumption patterns, excise taxes also give rise to a reduction in the supply of labour (greater tendency to choose leisure over work). As stated above with the example of an increase in the basic tax rate, a reduced supply of labour from raised excise taxes has therefore been calculated.

It is assumed that a budgetary equilibrium for public finances is required. Sooner or later, a revenue surplus following from increased income from taxes will therefore be evened out through a reduction in other taxes (or through higher public expenditure). The residual policy instrument (which is normally assumed to be a basic tax rate) will therefore be reduced by a similar amount. The compensating reduction in the basic tax rate reduces the distortionary effect of the basic tax rate on the supply of labour.

In this situation, the increased consumer expenditure due to taxes has a negative effect on the supply of labour, whereas the alternative funding which keeps the state's revenues unchanged has a positive effect on the supply of labour. Thus, it is important that the two effects on the supply of labour are always negative and positive, respectively. If the distribution profile from the tax and the residual policy instrument/the alternative good are identical, the two effects will cancel each other out. However, there will always be a triangular loss (A or B+C in the figure).

It may be argued, for some types of tax, that the effect of the excise tax on the supply of labour ought to differ from the distortionary effect caused by a proportional tax such as a basic tax rate. In situations in which special knowledge about the nature of the tax is lacking, it has been assumed that the tax corresponds to a proportional tax on consumption.

As a (sometimes) rough assumption, tax instruments are therefore considered to have a more or less neutral effect on the supply of labour when taking the compensating funding into account.

However, there will be an effect on the supply of labour from the triangular loss itself, from both the direct market and the derived market. The above triangular loss has therefore been raised by 20% to take account of the reduced supply of labour following from the triangular loss.

Distortionary effects of direct regulation (requirements and campaigns)

Overall, regulation can be understood in the same way as targeted taxes. For example, if regulation is introduced in the form of requirements for the use of a specific, eco-friendly technology that is more expensive than the current technology used, there will be a direct increase in the cost of the related activity. This occasions a distortionary effect in the goods market (triangular loss), as consumer spending is substituted away from the market equilibrium. The scope of this will depend on the existing tax burden on the good which consumption is substituted away from, in the direct market and possibly also in derived markets.

The effect of direct regulation in a taxed market is roughly outlined in figure 2, where q_1 illustrates demand after the direct regulatory instrument has been imposed. There is a loss in consumer surplus of B and in revenue for the state of C, which gives a total distortionary cost from reduced demand of B+C.

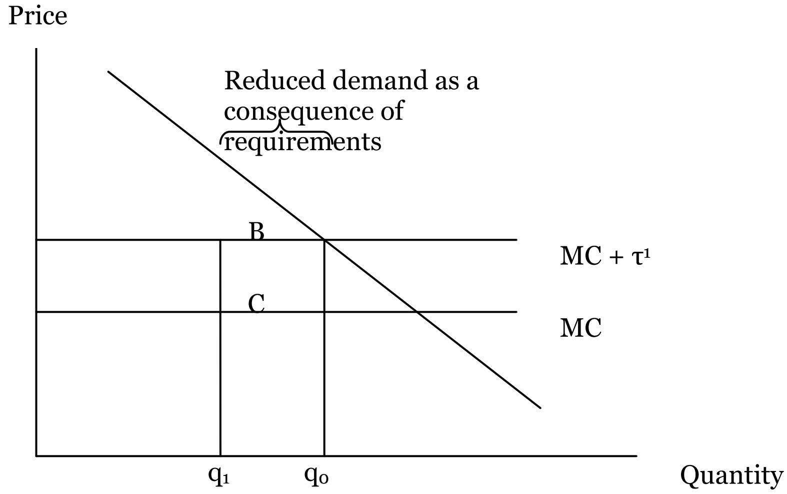


Figure 2 Illustration of distortion in the goods market from a requirement

However, B can rarely be estimated, as the slope of the demand curve is often unknown. As the distortionary effect of a tax can be roughly estimated, this leads to inconsistency between the welfare economic costs and benefits of various policy instruments. This should therefore be taken into account when making comparisons.

Losses in supply of labour

As stated above, the effect on supply of labour depends on the effect of the instrument on real disposable income. A regulation which requires a behavioural change away from the consumer's preferred consumption will reduce the utility value and have a direct effect on the supply of labour, however excluding the two special circumstances given below.

Furthermore, at the same time, the behavioural change can contribute to a revenue loss for the state if consumption of a taxed good is reduced in both the direct and any derived markets. Assuming there is a budgetary equilibrium, this revenue loss will be funded through other means and will result in a distortionary effect on the supply of labour. This will be the case, even if the instrument does not affect consumers' net burden directly, as in the two special cases above. For distortionary effects in the direct market (C) and effects in derived markets, the entire revenue effect is included as a part of the deadweight loss in the goods market, as is also the case for the calculation of the distortionary effect of a tax raise on the direct market and impact on the derived market.

The supply of labour is affected both by the possible loss of utility and by the revenue loss for the state, as it is assumed that this loss will have to be funded elsewhere.

Furthermore, there may be distortions which are not covered by the calculation methods available, including distortionary effects of direct requirements and nontradable barriers for consumer choices (transaction costs).

Distortions and transaction costs

In an ideal welfare economic analysis, the transaction costs can be valued and a total cost for society of the mitigation measures can be included in the calculations. Transaction costs may occur for instruments if there are barriers to changing behaviour. The distortionary effect on the goods market will be experienced as a loss of utility for consumers, because welfare economic analyses assume that the consumer acts rationally to optimise the utility of his budget constraint. If the consumer gets more utility from choosing the required eco-friendly technology, he will choose this solution, even in the absence of regulation.

The assessment of specific instruments should always be based on an assessment of the barriers causing the consumer to *not* act in a way deemed optimal. In this way, it might be possible to value the barriers. If solid information exists about the real transaction costs, this information can be used to estimate parts of, or the entire, loss of utility.

If regulatory instruments do not take account of the barriers, the welfare economic consequence of the measure will deviate from the anticipated. The loss from distortionary effects in connection requirements and campaigns which affect the direct financial burden is difficult determine, but it is no less important in order to determine the real costs for society of the behavioural instrument. If it is assumed that the consumer is in a situation in which a requirement could change his behaviour, this could be due to the fact that the value of the service flow from the required technology is lower than the technology that would have been chosen in the absence of the requirement. However, it has not been possible to value the reduced value. Other conditions could be decisions of a private financial nature, e.g. in relation to returns on investments and meeting funding requirements, as well as transaction costs of instruments, e.g. inconvenience of carrying out the technological investment.

In some situations, positive effects may arise from the behavioural instrument chosen, which originally was the reason the consumer did not choose the activity. The benefit of this should also be quantified and valued, if possible. A positive effect could be that large information barriers exist in an area. Here, the requirement or the information may be exactly what is needed to remove the information barrier, and the consumer can experience a net benefit which will also be included as a benefit in the welfare economic analysis. Distortionary effects of the requirement in the goods market can therefore be ignored.

Distortionary effects in the agriculture area

In general, a raised tax or other additional cost will lead to rising consumer prices and, thus, to distortionary costs for consumers; the triangular loss. At the same time, if the good being consumed is taxed (which is most often the case), there will also be a loss for the state, as state revenues from taxes are reduced.

However, contrary to other product markets, it will typically *not* be possible for the farmer to pass on the increased costs to consumers, because agricultural goods are exposed to competition from international markets and the farmer therefore has to accept the prices on these markets. Consequently, there are special calculation rules for measures in the agriculture area.

For measures that affect livestock farming or similar, the farmer will have the possibility of adapting his production. The total production of pigs, milk, etc. may consequently drop. If a production loss is too small to estimate with any certainty, the distortionary effect of this loss should not be included in the welfare economic calculations. If the farmer cannot adapt his production (significantly), then the increased costs will lead to a loss in income for the farmer, which will eventually mean less revenue for the state.

With measures that directly affect the profitability of farming the land, the increased cost means a lower rate of return, i.e. a lower economic rent. Because the price of land is determined by the discounted value of the economic rent, all else being equal, this will also lead to lower prices of land. Overall, a lower economic rent affects the income for the state from income taxes, indirect taxes, property taxes and taxes on property gains.

Distortionary effects in the agriculture area are calculated as follows: The cost of regulation for the farmer is calculated in factor prices (exclusive of the net-tax factor). On the basis of this cost figure, the loss for the state (in the form of lower revenue from taxation) can be calculated, and this amounts to 68%. The tax funding requirement for the state then has to be raised by the net-tax factor. Finally, the distortion in the supply of labour is calculated as approximately 20% of the total additional funding requirement for the state. Overall, this gives a welfare economic loss of 18% of the cost imposed on the farmer, calculated in economic terms, *see table 1*.

Table 1 Effect of measures that influence economic rent through increased costs, in DKK

Increased costs/fall in economic rent	100
Reduced income for the state (*see below*)	68
Additional funding requirement for the state (including net-tax factor)	92
Distortionary loss following from the cost (20% of the additional funding requirement of 92)	**18**

The lower revenue for the state from taxation or costs imposed on agriculture is relatively high, namely 68%. This is due partly to the effect on the farmer's income and consumption, and partly due to the effect on the land tax. In total, the state will lose income from land tax (14%), other markets (24.5%) and income tax (50%). This gives a total loss of around 68%.

For direct regulation (requirements, standards, orders, etc.)

Regulation causes the economic rent to drop, without providing a direct revenue for the state. There may, however, be derived revenue changes in other markets. This means that with direct regulation in the form of rules and orders, the state will not receive revenues to counterbalance the distortionary effect, and the distortionary cost should therefore be included in the calculations.

The distortionary effect of rules and orders is calculated as the distortionary cost in relation to the costs for the farmer (calculated in factor prices). The distortionary cost is estimated at 18%. If the direct regulation entails an increased cost for the farmer of DKK 100 in factor prices, then the distortionary cost will be DKK 18 in the welfare economic calculations.

The tax instrument

If regulation is in the form of raised taxes, a behavioural change will be expected, so that the tax base is reduced. If the area is already subject to taxation, this behavioural change will also affect old taxes, and there will be a distortionary cost (a quadrangular loss).

The tax imposes additional costs on agriculture, partly in the form of costs of the behavioural change (for farmers that change behaviour due to the tax), and partly in the form of expenditure on the new tax (for farmers that choose not to change behaviour but rather to pay the tax). In this case, only the distortion caused by the behavioural costs should be calculated, not the distortion caused by the new tax. The distortionary cost (or loss) is therefore 18% of the costs for agriculture of changing behaviour.

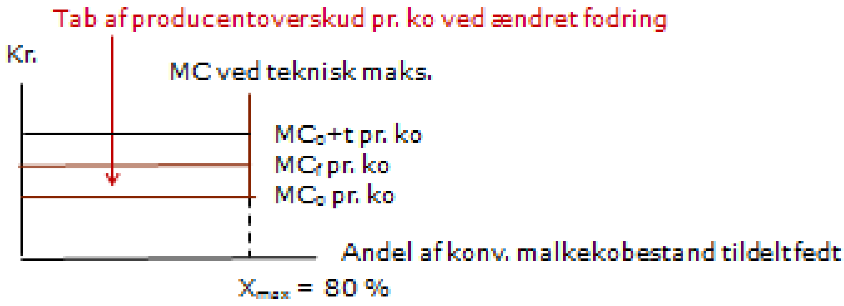
If the tax entails behavioural costs for agriculture of DKK 100 million (in factor prices) and revenue of DKK 200 million from the tax, then the distortionary cost is 18% of DKK 100 million, i.e. DKK 18 million.

On the triangular loss from taxes in the agriculture area

The loss of producer surplus cannot be calculated as a triangular loss assuming there are constant marginal costs. In the agriculture area, the marginal costs are assumed to be constant up to a technically defined maximum, after which the marginal cost curve is assumed (in principle) to be vertical. The loss of producer surplus under these assumptions is then the behavioural change multiplied by the average cost, i.e. a quadrangular loss.

For example, the following applies for a tax on feed without fat: For the given change in feed composition due to the tax, the marginal costs are assumed to be constant up to a technically defined maximum of 80% of the conventional stock of dairy cows, after which the marginal cost curve is assumed (in principle) to be vertical. The loss of producer surplus under these assumptions is illustrated in figure 3. The producers can choose to either change the feed composition, which increases the costs per cow from MC_0 to MC_f, or pay the tax, t per cow. As $t > MC_f – MC_0$ for 80% of the stock, the producers choose to change the feed composition for this percentage of the stock. The loss of producer surplus should therefore be calculated as number of cows that are given feed with fat multiplied by the average cost per cow of a changed feed composition.

Figure 3. Principle outline of reduced producer surplus of the measure involving changed feed composition for dairy cows



Source: IFRO

Calculations for all of the tax measures in the agriculture area (changed feed for other types of cattle; changed feed for dairy cows; nitrification inhibitors; and a tax on manure not used in biogas production) have been performed in this way, as the argument for all of these is the same as in figure 3 above.

Annex 2: Calculation of the national damage cost for PM2.5 and SO2 for point sources

The national damage cost for PM2.5

For rural areas, the total damage cost is DKK 88/kg (2012 prices) and it is estimated that 87% affects countries outside Denmark. This gives a national damage cost of DKK 11/kg PM2.5 (welfare-economic 2012 prices).

For urban areas, the total damage cost is DKK 111/kg PM2.5 and it is estimated that 68% affects countries outside Denmark. The national damage cost is then DKK 36/kg PM2.5 (welfare-economic 2012 prices).

The source of these calculations is tables 2.3 and 2.4 in "*Miljøøkonomiske beregningspriser for emissioner*" (environmental economic calculation prices for emissions), DCE technical report no. 783, 2010.

National damage cost for SO2

For urban areas, the total damage cost is DKK 73/kg SO2 (2012 prices) and it is estimated that 93% affects countries outside Denmark. This gives a national damage cost of DKK 5/kg SO2 (welfare-economic 2012 prices).

For urban areas, the total damage cost is DKK 94/kg SO2 and it is estimated that 72% affects countries outside Denmark. The national damage cost is then DKK 26/kg SO2 (welfare-economic 2012 prices).

The source of these calculations is tables 2.3 and 2.4 in "*Miljøøkonomiske beregningspriser for emissioner*" (environmental economic calculation prices for emissions), DCE technical report no. 783, 2010.