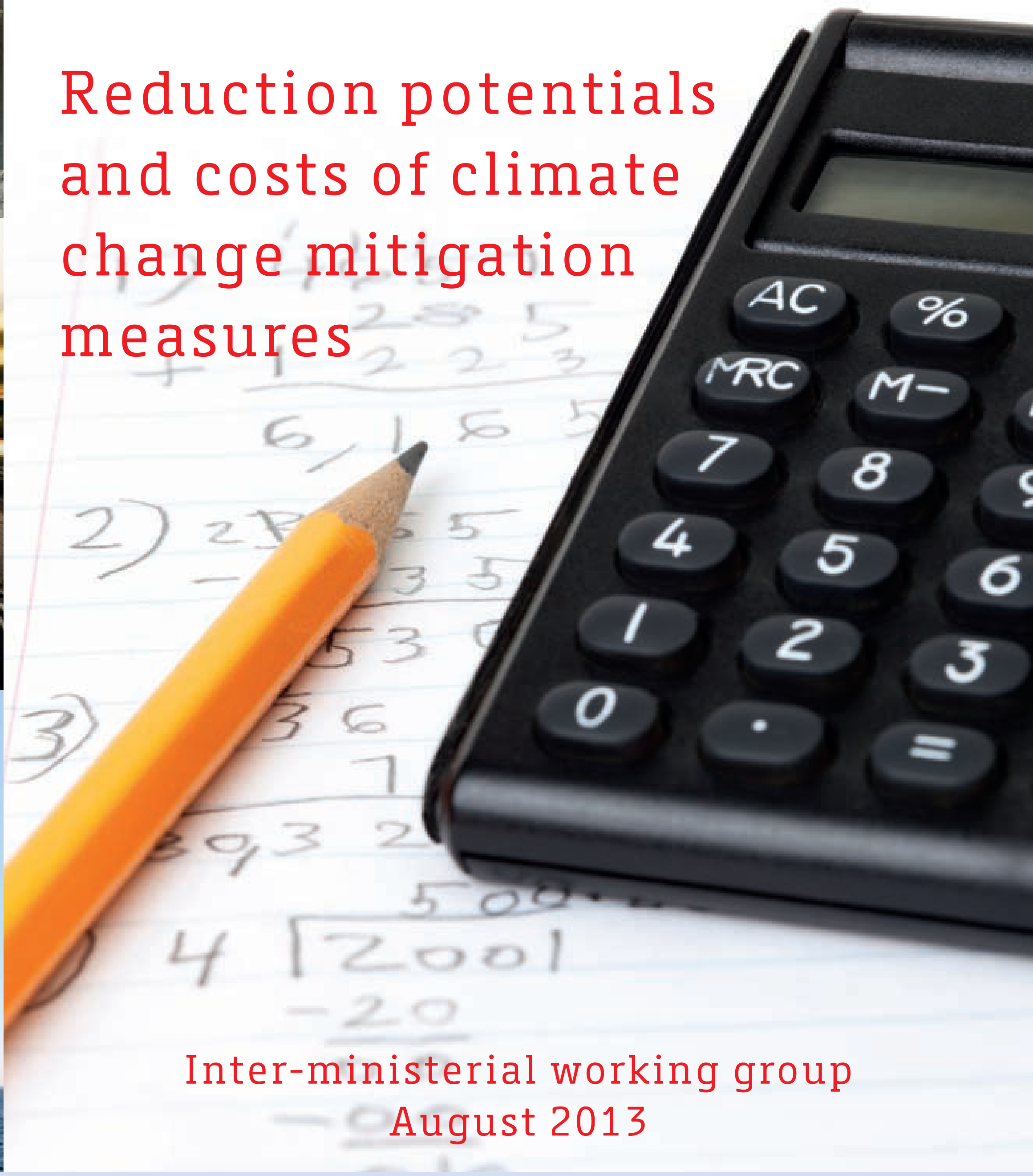



Catalogue of Danish

Climate Change Mitigation Measures

Reduction potentials and costs of climate change mitigation measures



Inter-ministerial working group
August 2013

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Introduction

This report contains material from the inter-ministerial working group on the reduction potential and costs of a series of analysed climate change mitigation measures. The assignment of the working group has been to assess the range and costs of possible measures that can contribute to reaching the national target of a 40% reduction of greenhouse gas emissions in 2020, relative to 1990. Analyses have been performed of the costs and reduction potential for a broad range of mitigation measures across various sectors, and with a wide selection of policy instruments.

Firstly, this report describes the method that has been used to analyse the welfare economic costs and benefits. This is followed by brief descriptions of the mitigation measures by sector (i.e. energy, transport, agriculture and the environment). Each section is introduced with a table showing the principal findings for all of the measures analysed for the relevant sector.

The methodology and assumptions are described in more detail in separate memos for each mitigation measure (in Danish only). These memos can be found on the website of the Danish Energy Agency. Here, you can also find a memo describing the methodology and the general assumptions in analyses of the measures.

The following Danish ministries have participated in the project:
Ministry of Climate, Energy and Building
Ministry of Finance
Ministry of Taxation
Ministry of Food, Agriculture and Fisheries
Ministry of the Environment
Ministry of Transport
Ministry of Business and Growth.

The Danish context and exchange rates

This publication is a one-to-one translation of the Danish publication "Virkemiddelkatalog – Potentialer og omkostninger for klimatiltag" from August 2013[1]. The results cannot be directly translated to other countries as the analysis is based on a considerable number of country-specific conditions and assumptions. Denmark is a high-income developed country characterised by relatively high taxes and a high level of environmental regulation. Denmark has achieved large greenhouse gas reductions compared to the reference year 1990 especially from the energy sector (read more about Denmark at www.Denmark.dk and www.stateofgreen.com).

The Climate Policy Plan of 2013 contains a situational analysis of Danish greenhouse gas mitigation efforts and the reference scenario of the expected development in greenhouse gas emissions in the future. All analyses in this publication are based on the reference scenario.

The shadow prices illustrating the greenhouse gas reduction cost of the specific policies and measures are shown in constant Danish prices (2012). In 2012 the average exchange rate from DKK to the four major currencies was:

	EUR	USD	GBP	CNY
Price in kroner for 100 units of the foreign currency	745.80	561.60	878.14	91.34

Source: Danmarks Nationalbank

1: Errors have been found in two of the measures (fixed cover on slurry tanks and afforestation). These errors have been corrected in this translated version.

CONTENT


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Analysis of welfare economic costs and benefits

The welfare economic method

The purpose of the analyses of this report is to provide information about welfare economic costs and benefits for a wide range of climate change mitigation measures. The analyses are based on a welfare economic method which is in line with the guidelines on welfare economic analyses from the Danish Ministry of Finance. The report includes an assessment of the reduction potential and the welfare economic costs and benefits of 54 mitigation measures, expressed as their 'CO_2 shadow price'. The analyses are based on the most recent knowledge about the effects, potentials, available technologies and prices of the mitigation measures in a Danish context as explained in the introduction.

Welfare economic analyses have not been carried out for some of the mitigation measures. This is because the available data and knowledge about these measures are not sufficient enough to allow for specific analyses. For example, this applies to measures that can contribute to increased carbon sequestration in Danish forests by use of breeding techniques. Such measures are only described qualitatively, because they represent areas in which knowledge is still inadequate.

Furthermore, it can be difficult to assess the mitigation potential of campaign activities aimed at greenhouse gas emission reductions through e.g. energy savings. Therefore, the welfare economic shadow price has not been analysed for these measures.

Key terms of the methodology used are described in the box below.

Explanation of terms

- Reduction potential specifies the amount of greenhouse gases by which a mitigation measure will be able to reduce the total emissions in Denmark in the year 2020. This includes emissions both inside and outside the ETS sector. The reduction potential of some of the mitigation measures can be scaled according to political decisions concerning a desired level. Often, determination of the reduction potential assumes possibilities up to a level where the marginal reduction costs rise sharply. For some mitigation measures the potential can only be scaled down, such as in the case of conversion of farmland for climate mitigation purposes. This is due to land constraints. The analyses apply to each measure in isolation, hence there can be an overlap of reduction potential between measures.
- The welfare economic costs and benefits indicate the total costs and benefits for Danish society. The welfare economic costs and benefits do not include the cash flow between the specific agents and institutions, such as taxes and subsidies, which only involve a redistribution between agents and institutions.
- The shadow price for a given mitigation measure expresses the welfare economic costs and benefits of reducing greenhouse gas emissions by one tonne CO_2 equivalent. This makes it possible, by comparing the shadow prices for the measures, to obtain an overall assessment of the most cost-effective mitigation measure from a welfare economic perspective.
- When the shadow price is negative, there will be welfare economic benefits for society from implementing a specific mitigation measure. The benefits could, for example, be the result of the welfare economic value of fuel savings and/or the value of co-benefits, such as the reduction of nitrogen discharges to the aquatic environment.
- Economic costs. The welfare economic costs and benefits, and thus the shadow price, do not express the costs of the mitigation measure for the central government, private households or businesses, respectively. The shadow price is therefore supplemented by assessments of the costs/benefits that a mitigation measure entails for the government, private households and business respectively. For example, it will make a significant difference in the distribution of cost and benefits for the government and the agricultural sector whether a reduction measure is implemented through subsidies or requirements.
- Carrying out a measure might well involve costs for specific agents or institutions in society, even if the measure has a negative shadow price.
- Only direct costs or benefits for government, business or households are analysed. Derived effects, such as reduced or increased competitiveness for enterprises, or distributional consequences, are not taken into consideration. These effects will need to be analysed in more detail as part of the legislative or policy process, if it should be decided to continue with a measure.

The key assumptions are shown in the box below. For a detailed outline of the method used, see the methodology memo published in connection with this report (see the preface).

Assumptions

- The CO_2 shadow price for a given mitigation measure expresses the measure's welfare economic reduction costs and benefits per tonne of reduced CO_2 eq. The shadow price is analysed as the net present value of the total welfare economic costs and benefits divided by the net present value of the total reduced quantity of CO_2, determined in tonnes CO_2 eq. The shadow price is expressed in DKK per tonne CO_2 eq.
- A discount rate of 4.00% is used in accordance with the Danish Ministry of Finance's guidelines for welfare economic analyses. The present value is analysed for the 30-year period from 2013-2042.
- The analyses are based on constant 2012 prices (see the introduction for relevant exchange rates).
- A policy instrument to encourage a specific mitigation effort is linked to each measure. The policy instrument could be, for example, a tax, a technology standard, a mandate or a subsidy. The distributional effects of the various instruments, such as taxes or subsidies, may differ considerably. The analysis of the welfare economic costs and benefits includes the so-called distortionary effects linked to the instrument. The methodology memo contains more information on distortionary effects.
- The economic costs of the measure are also shown, namely the direct additional costs to central government, households and business (which could refer to industry, the trade and service sector, agriculture, the energy sector, municipalities etc.). The economic costs are determined as annual costs distributed evenly over a 30-year period (2013-2042), i.e. as an annuity in DKK mill. per year. Thus, comparisons can be made between mitigation measures. However, there can be a great difference between the actual costs, especially in the first years, if the measure requires investment.
- A significant uncertainty is attached to welfare economic analyses with a long time horizon, because the costs and benefits are estimated.
- The value of co-benefits such as air pollution, noise, accidents, congestion, time-loss and emissions of nitrogen and ammonia are taken into account in the analyses, as far as possible. Shadow prices without co-benefits are analysed for all mitigation measures to ensure the comparability of measures.
- Some political priorities and concerns cannot be valued directly, and are therefore not included in the welfare economic analyses. This includes, for example, renewable energy targets.
- A number of derived benefits and disadvantages linked to the various mitigation measures are not included, such as the recreational value and biodiversity, as they cannot be directly valued. Effects on trade development, competitiveness, employment, regional development, spatial variation and social considerations, such as distribution of income, are similarly not assessed.

Note that determination of the welfare economic costs, benefits and CO_2 reduction potentials is subject to considerable uncertainty. This uncertainty depends on various factors, including the policy instrument chosen and the nature of the sector (including the type of greenhouse gas). The uncertainties are not the same across different regulatory instruments, such as taxes and standards, or across different sectors. Furthermore, is not possible to achieve complete consistency across instruments and sectors.

For example, the number of relevant co-benefits valued and included in the analysis can vary significantly between mitigation measures. In addition, the co-benefits for a number of mitigation measures are so significant that the measures' primary policy relevance can be others than climate change mitigation. For example, nitrogen reduction in agriculture could very well be the primary driver behind a given measure, i.e. the measure is primarily aimed at improving the aquatic environment. Another important reservation is that shadow prices for the specific measures cannot stand alone when there is a simultaneous commitment to prioritise measures that contribute to long-term green transition – for example, conversion of the energy sector to being independent of fossil fuels.

There is also uncertainty in the analysis of effect of the individual measure, for example, the extent of behavioural changes caused by the measure. With some mitigation measures there is considerable uncertainty connected with determining the barrier costs and consumer surplus.

Furthermore, knowledge, technology and other framework conditions are constantly improved. Assessment of shadow prices and potentials will always be a snapshot, requiring constant updating.

As far as possible, attempts have been made to include all the relevant behavioural changes for a specific measure in the analyses, including derived effects. However, it cannot be ruled out that, for some mitigation measures, there could be additional behavioural changes that are not included in the analyses.

Despite these reservations, the shadow prices are considered to be useful because they provide an insight into the possibilities available and they can help identify mitigation measures with relatively high or low welfare economic costs or benefits.

If the mitigation measure subsequently needs to be analysed in more detail, e.g. in connection with a new Bill, a more comprehensive and in-depth analysis will be performed, including all of the relevant behavioural effects. Similarly, more detailed clarification of a number of consequences will be drawn up, including effects on distribution, employment and state revenues. Business and administrative consequences will also be clarified. Furthermore, any matters concerning state aid or related to Community law will need to be clarified.

Negative shadow prices

In cases where the shadow price is negative, it is estimated that, all else being equal, the measure will result in a welfare economic surplus if carried out.

It is important to see reduction potential and the shadow price in context. A measure can have a very small or large shadow price in DKK per tonne CO_2 eq., but a very small reduction potential in tonnes CO_2 eq. In this case, the welfare economic surplus/loss from carrying out the measure could be large in DKK per tonne CO_2 eq. – while the absolute surplus/loss is very small.

There is also a specific problem concerning mitigation measures with negative shadow prices. Assume that a measure with a reduction of 10,000 tonnes CO_2 eq. per year has a welfare economic benefit of DKK 300,000 per year. The shadow price will be DKK -30/tonne CO_2 eq., and the present value of the total welfare economic benefits will be DKK 5.2 mill. over a 30-year period. When mitigation measures with negative shadow prices are compared conclusions may be misleading. If, for example, another measure with the same costs as above has a reduction potential of 15,000 tonnes CO_2 eq., i.e. 5,000 tonnes more than in the above case, then the shadow price will increase to DKK -20/tonne CO_2 eq., even though, in real terms, the measure is more advantageous as it has a greater total effect. If, on the other hand, the measure has an annual welfare economic cost of DKK 300,000 and thus a correspondingly positive shadow price of DKK 30/tonne CO_2 eq., then the shadow price will be reduced to DKK 20/tonne CO_2 eq., if the CO_2-effect is increased in the same way. Therefore, it is important to assess shadow prices in relation to the reduction potentials of the specific measures.

This also means that it is not possible to rank measures with negative shadow prices based on a comparison of their shadow prices.

Economic benefits to households and businesses

Some mitigation measures present an economic benefit for households and/or businesses. These measures should really implement themselves and incentives through subsidies or taxes should not be necessary. In these cases there will be barriers in the form of inconvenience, such as having to dig up your garden, having to employ workmen, etc. These barriers represent real costs. The barriers can also be due to lack of information or coordination etc., which causes citizens/enterprises to react irrationally to given price signals. These are also barrier costs, but they do not represent real cost of dealing with a barrier. Some measures apply standards, direct regulation, information etc. to overcome the barriers. In these cases, the instrument provides a benefit that can overcome the barrier, and the barrier costs are therefore not included in the analysis. For measures where the instrument is a tax, the barrier costs are implicitly included in the welfare economic analysis. It is assumed that an optimum state exists before regulation, and, therefore, any barriers are assumed to be the reason why the measure is not implementing itself, even though it presents an economic benefit. An estimate of barrier costs has been performed for the measures in question. Where barrier costs are deemed to be real costs, the magnitude of these costs has been estimated. The estimate is included in the welfare economic analysis and thus in the shadow price.

Energy

Consumption of fossil energy – oil, coal and natural gas – leads to CO_2 emissions and is the greatest single source of anthropogenic climate change. This section describes a number of mitigation measures in the Danish energy sector, i.e. energy consumption for electricity and heating production, and energy consumption by industry and households, which together account for around 57% of Danish greenhouse gas emissions. The measures include limiting fossil energy consumption and shifting to renewable energy, as well as a measure for carbon capture and storage.

Energy	Reduction	Shadow price	Net costs			
	Including carbon sequestration	Including co-benefits and carbon sequestration	State		Business	Households
	1,000 tonnes CO_2 eq. in 2020	DKK/tonne CO_2 eq.	Comments	Annuity DKK mill./year		
Measure with potential of more than 50,000 tonnes CO_2 eq.						
Stricter energy standards for new windows	59	-360		171	-57	-171
Reduced reimbursement of electricity charges for trade and service sector	1,111	886		-3,260	2,775	0
Reduced reimbursement of electricity charges for trade and service sector - with return of revenue	1,111	886		5	-490	0
PSO subsidy to construct 200MW nearshore wind farm (additional to energy agreement)	500	489		0	59	30
PSO subsidy to construct 200MW onshore wind turbines (additional to energy agreement)	450	55		0	30	15
PSO subsidy to construct 100MW photovoltaic solar modules in large installations	77	933		0	19	9
Subsidy for energy-efficiency improvement in business combined with ambitious implementation of the Energy Efficiency Directive	75	265	Subsidy DKK 500 mill. in the period 2014-2018	36	-43	0
Expansion of RE for production process scheme to include space heating	100	1,525	Subsidy pool DKK 1 bn. in the period 2014-2020	124	-132	0

Energy	**Reduction**	**Shadow price**	**Net costs**			
	Including carbon sequestration	Including co-benefits and carbon sequestration	State		Business	Households
	1,000 tonnes CO_2 eq. in 2020	DKK/tonne CO_2 eq.	Comments	Annuity DKK mill./year		
Expansion of RE for production process scheme to include new technologies	75	-201	Subsidy pool DKK 500 mill. in the period 2016-2020	35	-62	0
PSO subsidy for straw in CHP (without catch crops)	151	624		78	Energy sector -77 agriculture -46	-56
Measure with potential of less than 50,000 tonnes CO_2 eq.						
Energy saving mandate in public buildings	12	7,482	* Central government net energy expenditure DKK 31 mill./year, public investments DKK 157 mill./year 2013-2020	44 (31*)		0
Measure with effect after 2020						
Storage of CO_2 from power plants in oil fields in order to increase oil production (CCS/EOR) NB: no effect until after 2020 and no instrument	1,087	165 / 544	Shadow price of DKK 544/CO_2 eq. includes emissions from extra oil production	-307	Energy sector 257; oil companies private -467; oil companies public -117; carbon transporters 85	125
Measure, description only						
Free choice of fuel	0					
Tax for methane from refineries and oil production	0					
Information effort on electricity savings in private trade and service sector						
Subsidy for replacement of oil-fired boilers with heat pumps or district heating						

Stricter energy standards for new windows

Description
In this measure, energy standards for new windows in the building regulations will be tightened to provide a net energy gain of 15 kWh/m^2/year in 2020.

Assumptions
The current building regulations allow a net loss of 33 kWh/m^2/year, but up to 2020 it is expected that the permitted energy loss will be reduced to 0 kWh/m^2/year. Using statistics from Statistics Denmark and information from the window industry it is estimated that around 4.5 mill. m^2 of windows are replaced every year in Denmark, although this figure is subject to some uncertainty.

This analysis has been made on the basis of stricter requirements in the building regulations so that in 2015 windows will have to have a net heat gain of -5 kWh/m^2/year and in 2020 they will have to have a net heat gain of 15 kWh/m^2/year. The best windows on the market today give a net energy gain of more than 20 kWh/m^2/year.

The co-benefits of the mitigation measure are minor reductions of air pollution.

Analysis results
The measure is estimated to provide benefits, both in terms of private economies and from a welfare economic perspective, as the fuel savings exceed the additional costs to households buying more effective windows. Due to lack of information, it is expected that only few consumers will choose the most energy-effective windows, unless stricter standards are introduced. This could be partly due to the fact that in reality windows are often selected by the workmen that carry out the replacement.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, including co-benefits DKK/tonne CO_2 eq.	Shadow price, excluding co-benefits DKK/tonne CO_2 eq.	Net costs, Annuity, DKK mill./year		
				State	Business	Households
Stricter energy standards for new windows	59,000	-360	-366	171	-57	-171

Uncertainties
In the current building regulations there are certain exemptions from the component standards, as there can sometimes be constructional difficulties or aesthetic issues that conflict with the requirements. Possible future exemptions could reduce the potential.

There is some uncertainty surrounding the sale of windows and additional costs of improving windows.

Reduced reimbursement of electricity charges for the trade and service sector

Description
This measure consists of revoking or changing the reimbursement of electricity charges for the trade and service sector.

Assumptions
It is assumed that 25% of electricity consumption in the trade and service sector is non-reimbursable, but that it is possible to obtain reimbursement of electricity charges for the remaining consumption. In connection with this, note that reimbursement will be increased as a result of the Danish Plan for Growth (2013), and this has been included in the analyses. A number of professions are ineligible for reimbursement; however, this is not taken into consideration in the analyses.

The energy used by trade and service enterprises for purposes other than space heating is predominantly used for industrial processes. Analyses have been made on two versions of the policy instrument. Firstly, complete termination of the reimbursement for electricity consumption for industrial processes. The second version is a modified version, where the electricity charges are returned in full to the relevant sub-sectors. However, the total sum returned does not correlate to the charges paid; instead it is correlated to the number of employees.

If electricity charges are not refunded, there will be an increased financial incentive to implement energy savings. Termination of the reimbursement of electricity charges is anticipated to have a significant effect on electricity consumption in the trade and service sector, with a total reduction in energy consumption of 20% in 2020.

On the basis of the projected developments in Danish electricity production in the coming years, emission factors from marginal electricity production are applied up to 2025 – primarily coal-fired condensing power plants, after which the existing fossil capacity is expected to be gradually phased out. This explains the gradually decreasing emission factors for long-term marginal electricity production.

Analysis results
The welfare economic shadow price is relatively high, even though it is assumed there will be relatively large reduction potentials in the relevant sectors in which it will be economically cost-effective to use the measure, if the analyses are just based on additional costs obtained by deducting energy savings from the costs of purchasing more efficient equipment. This is due to a large welfare loss with such a high charge, and a significant loss of revenue from electricity taxes due to the electricity savings.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, including co-benefits DKK/tonne CO_2 eq.	Shadow price, excluding co-benefits DKK/tonne CO_2 eq.	Net costs, Annuity, DKK mill./year	
				State	Business
No reimbursement of electricity charges for trade and service	1,111,000	886	909	-3,260	2,775
Full return correlated to the number of employees	1,111,000	886	909	5	-490

Uncertainties
There is uncertainty concerning how the trade and service sector will react to the higher electricity price, including the extent of the barrier costs.

Public Service Obligation subsidy to construct 200MW nearshore wind farm

Description
In this measure a PSO subsidy will be granted for construction of a 200 MW nearshore wind farm, expected to be commissioned in 2016.

Assumptions
Analyses are based on the expected electricity price on the Nordpool market. It is assumed that investors will recover their investments including the required rate of return and expenses for operation and maintenance through PSO subsidies until year 14 of the facility's lifetime. After this, the plant's electricity production will be sold on market terms.

Mitigation measures that affect electricity consumption or production are subject to specific challenges with regard to assessing climate and welfare-economic impacts. This is due to the expected future developments in Danish electricity production over the coming years. Up to the year 2020 the development is driven by measures in the Energy Agreement, and then, after 2020, by future measures to realise the target of an energy system independent of fossil fuels by 2050 and the government's target for fossil-fuel-free electricity production by 2035. Therefore, it was decided to use emission factors from marginal electricity production up to 2025 – primarily from coal-fired condensing power plants, after which the existing fossil capacity is expected to be gradually phased out. This explains the gradually decreasing emission factors for long-term marginal electricity production.

Analysis results
The relatively high shadow price is due to investment as well as operational and maintenance costs that exceed the value of the electricity production from the wind turbines.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, including co-benefits DKK/tonne CO_2 eq.	Net costs, Annuity, DKK mill./year		
			State	Business	Households
200MW nearshore wind farm	500,000	489		59	30

Uncertainties
There is uncertainty regarding the emission reductions and the future price of electricity, whilst uncertainty concerning investment and operational costs is deemed to be relatively limited.

Public Service Obligation subsidy to construct 200MW wind turbines

Description
In this measure a PSO subsidy will be granted for construction of an additional 200MW onshore wind turbines on state-owned land, expected to be come into operation in 2016.

Assumptions
It is assumed that it is possible to find space for 200MW onshore wind turbines on state-owned areas, in addition to the sites identified by a screening in 2009. Land for approximately 50MW was identified at the 2009 screening, so there is a need to find areas for an additional 150MW through an additional screening of state-owned areas.

Analyses are based on the expected electricity price on the Nordpool market. It is assumed that investors will recover their investments, including the required rate of return and expenses for operation and maintenance, through PSO subsidies until year 7 of the facility's lifetime. After this, the plant's electricity production will be sold on market terms.

Mitigation measures that affect electricity consumption or production are subject to specific challenges with regard to assessing climate and welfare-economic impacts. This is due to the expected future developments in Danish electricity production over the coming years. Up to the year 2020 the development is driven by measures in the Energy Agreement, and then, after 2020, by future measures to realise the target of an energy system independent of fossil fuels by 2050 and the government's target for fossil-fuel-free electricity production by 2035. Therefore, it was decided to use emission factors from marginal electricity production up to 2025 – primarily from coal-fired condensing power plants, after which the existing fossil capacity is expected to be gradually phased out. This explains the gradually decreasing emission factors for long-term marginal electricity production.

Analysis results
The relatively low shadow price is due to the fact that the value of the electricity production largely matches the operational and investment costs.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, including co-benefits DKK/tonne CO_2 eq.	Net costs, Annuity, DKK mill./year		
			State	Business	Households
200MW onshore wind turbines	450,000	55		30	15

Uncertainties
There is uncertainty regarding the emission reductions and the future electricity price, whilst uncertainty concerning investment and operational costs is deemed to be relatively limited. There could also be uncertainty as to the actual potential as there is a considerable resistance to the installation of new wind turbines on land.

Public Service Obligation subsidy to construct 100MW photovoltaic solar modules in large installations

Description
In this measure a PSO subsidy will be granted for construction of 100MW photovoltaic solar modules in large, central installations after a tendering procedure and with operation from 2016.

Assumptions
Analyses are based on the expected electricity price on the Nordpool market. It is assumed that investors will recover their investments including the required rate of return and expenses for operation and maintenance through PSO subsidies in the first 15 years of the facility's lifetime. After this, the plant's electricity production will be sold on market terms.

Mitigation measures that affect electricity consumption or production are subject to specific challenges with regard to assessing climate and welfare-economic impacts. This is due to the expected future developments in Danish electricity production over the coming years. Up to the year 2020 the development is driven by measures in the Energy Agreement, and then, after 2020, by future measures to realise the target of an energy system independent of fossil fuels by 2050 and the government's target for fossil-fuel-free electricity production by 2035. Therefore, it was decided to use emission factors from marginal electricity production up to 2025 – primarily from coal-fired condensing power plants, after which the existing fossil capacity is expected to be gradually phased out. This explains the gradually decreasing emission factors for long-term marginal electricity production.

Analysis results
The high shadow price is primarily due to the high investment costs compared with the value of the electricity produced by the photovoltaic solar modules.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, including co-benefits DKK/tonne CO_2 eq.	Net costs, Annuity, DKK mill./year		
			State	Business	Households
100MW photovoltaic solar modules, large installations	77,000	933		19	9

Uncertainties
There is uncertainty on the emission reductions and the future price of electricity, whilst uncertainty concerning investment and operational costs is deemed to be relatively limited.

Subsidy for energy-efficiency improvement in business combined with ambitious implementation of the Energy Efficiency Directive

Description

The mitigation measure consists of a subsidy pool of DKK 100 mill. per year for five years from 2014 for energy-efficiency improvements in manufacturing industry.

Assumptions

The measure combines three main elements: Requirements will be introduced for energy audits and/or energy management in significantly more and smaller enterprises than the minimum requirements in the Energy Efficiency Directive. A newly established data and knowledge centre will be expanded with knowledge from the new energy audits and will be made available for energy advisors, energy enterprises etc. Finally, investment subsidies for energy-efficiency measures will be granted to enterprises. The core mitigation measure is the establishment of a subsidy scheme. However, this will be supported by the promotion of energy audits and information and campaign efforts. The effect is analysed on the basis of the subsidy scheme, but the costs of information activities and a broad interpretation of the enterprises subject to the measure are also included in the analyses.

An average investment of DKK 4.5/kWh and a lifetime of 15 years for investments has been assumed. It has been assumed that 70% of the subsidy funds will be used for investments with long pay-back periods. It is furthermore assumed that 50% of the investment potential will be carried out regardless of the subsidy. In total, it is expected that the mitigation measure will lead to an energy saving of 0.6PJ.

There is a potential overlap with other proposed subsidy schemes for the business sector and with energy consultancy by energy companies.

Analysis results

The relatively low shadow price can be explained by the fact that the value of the energy savings exceeds the investment costs. Additionally, the losses of revenue from energy taxes are relatively small, as the manufacturing industry only pays limited energy taxes.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, including co-benefits DKK/tonne CO_2 eq.	Net costs, Annuity, DKK mill./year	
			State	Business
Subsidy for energy-efficiency improvements in businesses, combined with ambitious implementation of Energy Efficiency Directive	75,000	265	36	-43

Uncertainties

There is great uncertainty about the effect of the subsidy, in part because there are three sub-activities, and also because the energy companies are already subject to a considerable energy-saving efforts.

Expansion of RE for production process scheme to include space heating

Description

This mitigation measure consists of expanding the subsidy framework for the renewable energy production process scheme so that it will also support the establishment of installations to use renewable energy for space heating production in business.

Assumptions

Subsidies for a total of 3PJ space heating are anticipated. A subsidy for, on average, 50% of the investment with a 6-year payback period is assumed. Furthermore, it is assumed that 50% of the investment potential will be implemented without any subsidy – in other words, only 50% of the savings from supported projects will be attributable to the subsidy scheme.

There is an assumed barrier cost for enterprises and this has been assessed by assuming a higher discount rate for enterprises than in the welfare economic analysis. As the measure is generally outside enterprises' core business, a high required rate of return is assumed – 15% per year for the assessment of the barrier costs.

A tax payment is assumed following from the difference in security of supply tax for renewable energy and fossil energy sources respectively, rising from DKK 0/GJ in 2014 to DKK 7.9/GJ in 2019 and thereafter. In the reference scenario it is assumed that the energy tax will be DKK 59.4/GJ and the CO_2 tax will be DKK 11/GJ (mix of natural gas and oil).

Analysis results

The high shadow price is due to the fact that investment costs are only slightly lower than the energy savings and there is a loss of revenue for central government from energy taxes.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, including co-benefits DKK/tonne CO_2 eq.	Net costs, Annuity, DKK mill./year	
			State	Business
Expansion of RE for production process scheme to include space heating	100,000	1,525	124	-132

Uncertainties

There is uncertainty regarding the effect of the subsidy scheme, future energy prices etc. The uncertainty concerning investment and operational costs is considered to be relatively limited.

Expansion of RE for production process scheme to include new technologies

Description
This measure proposes an expansion of the renewable-energy-process subsidy scheme to include new technologies for renewable energy for industrial process purposes – for example, gasification of biomass.

Assumptions
A subsidy of, on average, 50% of the investment with a 6-year repayment period is assumed. Furthermore, it is assumed that 50% of the investment potential will be implemented without the subsidy – in other words, only 50% of the savings from supported projects will be attributable to the subsidy scheme. Subsidies for a total of 2PJ RE for new process technologies are anticipated. The subsidies are also expected to lead to energy savings of 1.4PJ/year in 2020.

Analysis results
The shadow price is negative as the savings exceed the costs of investment and operations, as well as the loss of revenue from energy taxes for central government.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, including co-benefits DKK/tonne CO_2 eq.	Net costs, Annuity, DKK mill./year	
			State	Business
Expansion of the RE for production process scheme to include new technologies	75,000	-201	35	-62

Uncertainties
The uncertainties concerning the determination of the emissions reduction are described under the assumptions. There is also uncertainty regarding the future price of electricity. There is little uncertainty regarding the investment and operational costs.

Public Service Obligation subsidy for use of straw as fuel in Combined Heat and Power production (CHP)

Description

This measure involves supply of 350,000 tonnes of straw for use in the Combined Heat and Power production (CHP sector), in combination with an increased Public Service Obligation top-up on electricity production.

Assumptions

The potential for increased straw supplies for energy purposes is estimated to be equivalent to the production of straw from 100,000 hectares of agricultural land in 2020. It is assumed that the increased straw supplies will not replace other obligations for biomass use. An increase in Public Service Obligation supplement of DKK 0.05/kWh in addition to the existing DKK 0.15/kWh is assumed. The increased use of straw removed from the fields will result in a carbon loss from agricultural soils, which has been taken into account in the analysis.

Analysis results

It is decisive for the shadow price whether the effect of catch crops is included in the analysis or not. This measure is analysed without catch crops. If catch crops are planted, then the shadow price will be reduced. However, it should be noted that these catch crops can be planted without an increase in the use of straw.

	Reduction, including carbon sequestration, tonnes CO_2 eq. 2020	Shadow price, including carbon sequestration, without catch crops, including co-benefits, DKK/tonne CO_2 eq.	Net costs, Annuity, DKK mill./year			
			State	Agri-culture	Energy sector	House-holds
PSO subsidy for straw for CHP	151,000	624	78	-46	-77	-56

Energy saving mandate for public buildings

Description

In this measure, an additional 5% energy savings, on top of those stated in the energy agreement from 2008, will be required from central government building owners.

Assumptions

In the 2008 energy policy agreement, it was approved that energy-saving efforts by ministries should be strengthened. A target of a 10% reduction in energy consumption from 2006 to 2011 was subsequently established. Costs and effects of the measure have been estimated on the basis of the assumption that consumption is actually amended as stipulated in the measure.

The analyses are therefore based on an additional reduction in energy consumption in public buildings of 5%.

The energy savings are assumed to have a lifetime of 30 years. The costs are related to the implementation of a required 5% reduction of energy consumption over 8 years, 2013-2020, in which DKK 157 mill. per year will be invested. The price per square meter is determined on the basis of average figures and includes both direct energy measures (insulation of heating pipes, adjustment of BAS system, installation of double glazing etc.) and energy measures that must be implemented simultaneously with other maintenance to be financially viable (for example, insulation when replacing roof or façades, low-energy windows). It is assumed that state institutions carry out ongoing maintenance of their buildings within the general budget. Half of the 5% energy savings are realised as part of the general maintenance at the marginal costs of energy renovation. The remaining 2.5% savings are expected to require an additional investment for both the maintenance activity and the energy measure.

Analysis results

The shadow price for this measure is relatively high. This is due to the strict requirements for implementing energy savings, this means that efforts are accelerated and not solely implemented in conjunction with other building renovation work up to 2020. The energy renovations are most cost-effective when they can be implemented simultaneously with other building renovation work.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, including co-benefits DKK/tonne CO_2 eq.	Net costs, Annuity, DKK mill./year State
Energy saving mandate in public buildings	12,000	7,482	44

Uncertainties

There is uncertainty regarding future energy prices

Storage of CO_2 from power plants in oil fields in order to increase oil production (CCS/EOR)

Description

This measure consists of storing CO_2 from power plants in oil fields in order to increase oil production. In the analysis presented there is an effect of 1.1 mill. tonnes in the first year. However, with current technology it is not expected that the project will be ready for implementation in 2020, thus this measure cannot contribute to reaching the 40% target for 2020.

Assumptions

The analysis for this measure has been carried out without a specific instrument to ensure its implementation. Thus, the results of the analysis cannot be compared directly with the other measures in this publication. CO_2 from thermal power plants is injected into oil fields, partly in order to increase oil production relative to conventional extraction methods, and partly for permanent storage of CO_2. This process is known as Carbon Capture and Storage/Enhanced Oil Production (CCS/EOR).

The instrument is designed so that CO_2 is captured from three central, Danish power plants; starting around 2020. The CO_2 is transported by ship to three oil fields in the North Sea, where it is pumped down to the oil-bearing layers. CO_2 that comes up with the oil is re-injected back into the oil fields. When the oil fields are empty the boreholes are sealed, after which the CO_2 is assumed to be permanently stored. The CO_2 capture process is rather energy-intensive, and it is estimated to reduce the power plants' electrical efficiency by up to 10%. Moreover, production of heat for district heating will be halved, making it necessary to find alternative means for heat production. Emissions from these alternatives are offset in the stored CO_2. The analyses are based on a gradual start from 2020, and from 2027 it is estimated that the reduction could reach 4.5 mill. tonnes per year; without deduction of the emissions from the extra oil production. This level can be maintained until 2042, after which it will decrease to 0 in 2050.

In total, this measure could lead to a reduction in Danish CO_2 emissions of around 95 mill. tonnes for the entire period. Or a total reduction of 28 mill. tonnes, if increased oil production from injecting CO_2 into oil fields is taken into account, as this itself will lead to additional emissions when the oil is used. The international regulations for determination of CO_2 require that emissions from all energy consumption are attributed to the country where the consumption takes place. As the extra oil from a CCS/EOR project is not expected to increase Danish oil consumption, the additional emissions from this oil will be attributed to another country in which the oil is consumed. Like many of the other mitigation measures in the Climate Policy Plan, the project period for this measure is expected to be around 30 years, but the start date will be later than for the other mitigation measures, and the project is unlikely to start by 2020.

The analysis example and table below illustrate the immediate economic revenues and costs for the involved agents and institutions. It is assumed that no payments are made between the specific agents and institutions – apart from tax payments as a result of the relevant fiscal regulations.

Analysis results

The relatively high shadow price cannot be compared with shadow prices in the other measures, as no implementation instrument has been included in the table below. There are two different shadow prices. The shadow price including traditional co-benefits is more or less identical with the shadow price excluding co-benefits, and these are therefore presented together in the table. Finally, an extra shadow price is included which takes into account the emissions that the consumption of the extra oil will lead to.

A separate analysis has been made which can illustrate the scale of an instrument. In this analysis it is assumed that the oil companies pay the costs of CO_2 uptake in power plants and for transport of CO_2 from power plants to oil fields. It is furthermore assumed, that the oil companies require a return on their investments of 15%. With these assumptions, the oil companies will have an economic deficit of around DKK 7.4 billion, which it is assumed will be paid by central government. This analysis is not included in the table.

	Reduction, tonnes CO_2 eq.	Shadow price, including co-benefits	Shadow price including effect of the extra oil emissions	Net costs, Annuity, DKK mill./year				
	First year	DKK/tonne CO_2 eq.	DKK/tonne CO_2 eq.	State	Oil companies private/ public	Power plants	Companies transporting CO_2	District heating consumers
CCS / EOR	1,087,000	165	544	-307	-467 / -117	257	85	125

Uncertainties

There is considerable uncertainty regarding many of the important parameters in this analysis: Oil prices can differ significantly from the prognosis applied. The extent of the extra oil production per injected tonne of CO_2 is estimated using other types of geological oil deposits than those found in Denmark and from laboratory trials. Finally, investment costs of offshore facilities are subject to considerable uncertainty as the CCS/EOR process has not previously been undertaken on offshore oil fields. The economic analyses are therefore very uncertain. However, it is relatively certain that the reduction potential is high.

Qualitative descriptions of energy measures

Free choice of fuel

Description

In this measure, a free choice of fuel will be introduced for small-scale CHP plants and district heating plants with a capacity greater than 1MW.

Free choice of fuel reduces natural gas consumption and thus CO_2 emissions in the non-ETS sector. At the same time, small-scale electricity production is reduced. As the production that is lost is CHP, there need to be an available, unmet heating demand at the large-scale plants, to enable the replacement electricity production to take place as CHP. This, however, is not the case. Similarly, renewable energy electricity production by wind turbines cannot be adjusted. The electricity previously produced as CHP, must therefore be produced by condensing power – primarily at the large-scale power plants.

A proportion of the electricity production that is displaced by free choice of fuel will probably be imported – although a significant share of the adjustable thermal capacity in the Nordic countries is Danish. This means that the actual CO_2 emissions in Denmark could fall. The total adjusted CO_2 emissions used in the analysis for the 40% target, will, on the other hand, be largely unchanged, as the determination of total CO_2 emissions has been adjusted for electricity trading. Free choice of fuel has therefore no significant CO_2 effect in relation to achieving the 40% target.

Condensing power plants will continue to run on coal, even though the large scale power plants are converted to biomass for CHP. It is the tax benefits concerning heat production that motivate the biomass conversion. As there is no tax on coal for electricity production, then coal will be much cheaper than biomass if the heat cannot be used. It is therefore likely that coal-fired condensing power plants will also represent the average marginal electricity consumption in 2020, and that they will form the basis for adjustments for trade in electricity.

This means that the effect that free choice of fuel might have on the actual CO_2 emissions is neutralised by the adjustment for electricity trading.

In practice, Greenhouse gas emissions from electricity production in Denmark will depend on Danish competitiveness compared with electricity production in neighbouring countries. The extent to which the actual 2020 emissions are higher or lower than the adjusted emissions will depend greatly on how the electricity exchange develops. This varies from year to year and is very sensitive to factors such as rainfall (precipitation) in the Nordic countries and outage time for power plants, including nuclear power.

On this basis, it is concluded that the free choice of fuel instrument should not be included in the analyses for the Climate Policy Plan, as there is no CO_2 effect contributing to the 40% target.

Tax on methane from refineries and oil production

Methane is emitted during extraction of oil and gas. There are emissions both from the energy consumption of the gas turbines on the drilling platform and from flaring (burning off gas for technical and safety reasons). There is also evaporation of methane during extraction and secondary processing.

Consumption of own fuel to produce similar fuels (refineries etc.) is exempt from, for example, mineral oil tax, CO_2 tax and sulphur tax.

This exemption follows from EU regulations.

It will therefore not be possible to impose taxes on emissions that concern extraction and secondary processing. It is also unclear whether the emissions from energy consumption of gas turbines on drilling platforms and flaring can be made subject to taxes.

In 2010, 125,000 tonnes CO_2 equivalents were emitted from refineries and oil production. It is, however, unclear how these emissions are distributed amongst the different activities.

Information effort on electricity savings in the trade and service sector

Description

This measure consists of a comprehensive information effort targeted towards electricity savings in the trade and service sector, with special focus on the sub-sectors that currently have the majority of their electricity taxes refunded.

Assumptions

It is estimated that there is an unexploited savings potential in the trade and service sector. For the sectors where most of the electricity taxes are refunded, motivation to implement energy-saving measures is genuinely low. Therefore an information and guidance effort could be appropriate.

The effect of the measure must be estimated in relation to a scenario where the energy companies' energy-saving obligations are doubled in the coming years. This means that energy companies will increasingly focus their energy-saving efforts on the trade and service sector. The obligation has become so comprehensive that the primary focus area of energy companies is expected to be extended.

This means that the proposal for a more intensive information effort should be compared with the reference scenario in which energy companies are already expected to increase their efforts considerably. The reduction potential of the measure is therefore uncertain.

Subsidy for replacement of oil-fired boilers with heat pumps or district heating

Description

In this measure, a subsidy is proposed for replacing oil-fired boilers with either heat pumps outside district heating areas or district heating in areas where district heating is available.

The advantage of this proposal is that fossil fuel is replaced by district heating, which to a large extent is based on renewable energy. There are still around 175,000 oil-fired boilers in homes outside collectively supplied areas and around 25,000 oil-fired boilers within district heating areas. Under the oil-fired boiler scrapping scheme, around 10,000 heat pumps and 10,000 district heating installations were installed in roughly one year.

Transport

CO_2 emissions from the transport sector account for around 22% of total greenhouse gas emissions in Denmark. This section describes a number of mitigation measures for reduction of energy consumption in the transport sector and conversion to fuels with a lower impact on the climate.

Transport	Reduction	Shadow price	Net costs			
	Including carbon sequestration	Including co-benefits and carbon sequestration	State		Business	Households
	1,000 tonnes CO_2 eq. in 2020	DKK/tonne CO_2 eq.	Comments	Annuity DKK mill./year	Annuity DKK mill./year	Annuity DKK mill./year
Measure with potential of more than 50,000 tonnes CO_2 eq.						
Reduction of maximum speed on motorways	63	13,460	Investment DKK 5 mill.	77	-44	-191
Abolition of commuter mobility tax deductions	130	4,167		-3,800		3,800
Kilometre based road tax for cars, vans and motorcycles	1,315	4,181	Investment DKK 4.4 bill.; Operation DKK 1.6 bill./year	-2,786	-2,692	-4,764
Green Development Tax on fossil fuels	186	2,409		-61	163	255
Increase of fuel taxes by DKK 0.40/litre	743	2,663		-133	594	965
Increased biofuel blending mandate	163	1,499		105	45	66
Statutory requirement for 1% advanced biofuel in petrol from 2020	85	4,455		175	15	142
Measure with potential of less than 50,000 tonnes CO_2 eq.						
Compulsory driving lessons on energy-efficient driving techniques	17	1,189		10	1	19
Subsidy to and certification of private-municipal collaboration on green commercial transport	30	-585	Business and municipalities	22	-31	0
Vehicle procurement requirements for the public sector	42	235	Business and municipalities	9	-10	0
Biofuel blending subsidies for heavy vehicles	39	1,581	Subsidy DKK 244 mill.	14	0	0
Extended tax exemption for electric cars extended after 2015	16	4,462		51	0	-9
Tax exemption for plug-in hybrid cars 2013-2015	7	5,012		27	0	-6

Transport	**Reduction**	**Shadow price**	**Net costs**			
	Including carbon sequestration	Including co-benefits and carbon sequestration	State		Business	Households
	1,000 tonnes CO_2 eq. in 2020	DKK/tonne CO_2 eq.	Comments	Annuity DKK mill./year	Annuity DKK mill./year	Annuity DKK mill./year
Tax relief on natural gas for heavy transport	2	1,798		15	-60	0
Promotion of natural gas for the transport sector through subsidies for natural-gas-powered heavy goods vehicles	0.3	941	Subsidy DKK 45 mill./ year for 3 years	-1	-4	0
Measure, description only						
Preparation of a bicycle strategy to promote cycling						
Pilot programme for energy-effidient transport solutions						
Support for production of advanced biofuels						
Revenue-neutral tax reform for passenger cars	Depending on the nature of the reform					
European Union regulatory developments for vehicle technology						
– Reduction of speed limit for lorries from 90 to 80km/h	150					
– Intelligent speed adaptation for cars and vans	20					
– Allowing more aerodynamic cabin design for lorries	50					
EU 2020 recommended targets for CO_2 emissions from cars and vans made mandatory	210-350					
Subsidy for demonstration projects regarding goods distribution outside rush hour	3-15					
Subsidies for campaigns on energy-efficient driving techniques	7					
Subsidies for campaigns about energy labelling of cars and vans	3					
Subsidies for campaigns promoting energy-efficient tyres	6					
Subsidies for courses in energy-efficient driving for municipalities and transport operators	5					

Reduced maximum speed on motorways

Description
This measure involves reducing the maximum speed limit on motorways from 130km/h to 110km/h. High speed is generally associated with greater CO_2 emissions per driven kilometre, so a reduction of speed on the motorway network to 110km/h will result in a CO_2 reduction.

Assumptions
The majority of vehicles on the Danish road network are most energy-efficient at speeds around 80-90km/h. A reduction in the speed limit on the motorway network to 110km/h will give a CO_2 reduction. It has been assumed that, in practice, speeds will be reduced by 10km/h from an average of 122km/h to 112km/h.

There will be a cost to the regulatory agency associated with setting up 110km/h signs on the existing 130km/h network. A sum of around DKK 5 mill. is assumed for sign replacement in the period 2013-2020. There will be an additional loss of revenue for the state from fuel taxes, estimated at around DKK 75 mill. per year.

As a co-benefit there will be reduced public expenditure as a result of fewer and less serious road accidents, which gives a welfare economic saving. Reduction of the legal speed limit will give increased transport times and thus a lower mobility, which is included as a welfare economic cost.

Analysis results
Reduction of the legal speed limit on the 130km/h network will lead to a welfare economic loss due to increased transport time. Savings from the reduction in traffic accidents are also included in the shadow price. This gives a difference in the analysed shadow price depending on whether co-benefits are included or not.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, including co-benefits DKK/tonne CO_2 eq.	Shadow price, excluding co-benefits DKK/tonne CO_2 eq.	Net costs, Annuity, DKK mill./year		
				State	Business	Households
From 130km/h to 110km/h on motorways	63,000	13,460	16,582	77	-44	-191

Uncertainties
There is some uncertainty regarding the effect of the measure as the average speed can vary.

Abolition of commuter mobility tax deductions

Description

This measure consists of the removal of tax deductions for commuters' transport to and from work. This will especially reduce private car use and the associated fuel consumption and CO_2 emissions.

Assumptions

Tax allowances are given for travel to and from work for a total round trip of more than 24 kilometres per day. The total transport covered per year is around 7.4 billion kilometres. It is estimated that private car use makes up around 5.2 billion kilometres whilst public transport accounts for around 2.2 billion kilometres. Abolition of the deductions for transport between work and home is estimated to reduce total transport by around 1.1 billion kilometres, corresponding to around 15%, of which around 0.8 billion kilometres relates to private car use. It is estimated that this will lead to a fall in fuel consumption corresponding to around 33.5 mill. litres petrol and 22 mill. litres diesel. The measure will lead to co-benefits in the form of reduced congestion, fewer accidents and less noise as the volume of traffic falls.

Analysis results

The abolition of tax deductions for transport to and from work will be associated with a high shadow price and state revenue increases that can be converted to other allowances or taxes. The welfare economic costs reflect the reduced consumer spending entailed by removing the tax deduction. Co-benefits consist of a reduction in congestion, fewer accidents and less noise as the total volume of traffic falls.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, including co-benefits, DKK/tonne CO_2 eq.	Shadow price, excluding co-benefits DKK/tonne CO_2 eq.	Net costs, Annuity, DKK mill./year		
				State	Business	Households
Abolition of tax deductions for transport to and from work	130,000	4,167	8,703	-3,800		3,800

Uncertainties

There is some uncertainty about the effect of the measure, for example the proportion of private vehicle use that will be effected by the abolition of the deductions.

Kilometre based road tax for cars, vans and motorcycles

Description
In this measure, a Danish, kilometre-based road pricing tax is analysed as an instrument to reduce road traffic and fuel consumption, thus reducing CO_2 emissions.

Assumptions
One of the tasks of the Danish congestion committee was to clarify the possibilities for road-pricing on a national basis. The Commission presented its final recommendations to the government in September 2013. The measure is therefore based on adjusting the cost of driving cars or vans, but not where or when the journey takes place. It is thus the general influence on the volume of traffic that creates CO_2 reductions. The analyses assume the establishment of a GPS-based taxation system, with a charge of DKK 0.25 per kilometre for cars, vans and motorcycles. A proportion of the traffic will disappear, which will give rise to a welfare loss when an individual no longer undertakes an otherwise planned journey. On the other hand, motorists on sections of road with less traffic will experience a gain due to improved accessibility. The investment costs are estimated at around DKK 4,368 mill. and the annual operating costs are estimated at around DKK 1,638 mill..

The measure will have co-benefits in the form of reduced travel times for the remaining motorists and fewer accidents; both of these because of the expected drop in traffic volume.

Analysis results
The high shadow price is primarily due to the fact that limiting transport work leads to reduced mobility and lower revenues from transport-related taxes. The difference in the welfare economic shadow price with and without co-benefits, respectively, is due to the value of time, accidents and, to a lesser extent, reduced noise and atmospheric pollution.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, including co-benefits DKK/tonne CO_2 eq.	Shadow price, excluding co-benefits DKK/tonne CO_2 eq.	Net costs, Annuity, DKK mill./year		
				State	Business	House-holds
Kilometre based road tax for cars, vans and motorcycles	1,315,000	4,181	10,151	-2,786	-2,692	-4,764

Uncertainties
Supplementary sensitivity analyses found that doubling the rate to DKK 0.50 per kilometre gives a shadow price of DKK 4,458. The shadow price is thus not sensitive to the size of the tax. Similarly, the discount rate has little effect on the result. However, the results are generally very sensitive in relation to the different assumptions, for example, regarding elasticity and costs.

Green Development Tax on fossil fuels

Description
In this measure, a separate tax is imposed on fossil fuels (diesel and petrol) for transport. The revenue is earmarked to develop green solutions for the transport sector.

Assumptions
The immediate effect of the increased tax will be the same as an increase in fuel taxes. For example, the derived effects of increased fuel prices will lead to a significantly lower revenue for the state via reduced fuel sales, increased border trade, derived effects on vehicle taxes etc., this will lead to a significant reduction in the direct revenue surplus for the state as a result of the tax increase.

The analyses are based on a rise in taxes of DKK 0.1 per litre of fuel. The total reduction in CO_2 emissions in 2020 following a DKK 0.1/litre increase in the fuel tax is estimated to be around 186,000 tonnes CO_2. The surplus revenue for the state, to be used to promote green solutions in the transport sector, is estimated at around DKK 60 mill. per year, which could contribute to additional CO_2 reductions.

It should be noted that it is generally not advisable to operate with designated sources of funding, as designated implementation within a specific sub-sector prevents a cost-effective allocation of funds across the economy.

Analysis results
The high shadow price is especially due to the additional expenses for buying fuel and the large reduction in revenue due to reduced fuel sales, an expected increase in border trade and losses from other vehicle-related taxation. On the other hand, there will be fewer accidents, as well as reduced congestion, noise and atmospheric pollution.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, including co-benefits DKK/tonne CO_2 eq.	Shadow price, excluding co-benefits DKK/tonne CO_2 eq.	Net costs, Annuity, DKK mill./year		
				State	Business	Households
Green Development Tax on fossil fuels	186,000	2,409	3,374	-61	163	255

Uncertainties
The results are sensitive to the assumptions regarding, for example, elasticity, border trade effect etc.

Increase in fuel tax of DKK 0.4/litre

Description
In this measure the existing tax on fuel for transport purposes (diesel and petrol) is increased.

Assumptions
An increase in tax on diesel and petrol of DKK 0.4/litre is assumed.

This reduces domestic fuel sales, partly as a result of a fall in fuel consumption and partly as a result of increased border trade in petrol and diesel. The reduction in domestic fuel sales is a result of fewer kilometres driven and improved fuel economy.

It is assumed that a rise in the price of DKK 0.01/litre excluding VAT will lead to a fall in consumption of 0.04%. A DKK 0.4/litre increase is therefore estimated to give a total consumption reduction of 1.6%. An isolated Danish price increase must be expected to lead to increased border trade in diesel and petrol. It is also assumed that a tax increase of DKK 0.4/litre displaces around 4% of the domestic sales to other countries.

The total domestic fall in fuel sales and associated CO_2 emissions in Denmark have been included in the analyses of CO_2 reductions in Denmark. The analysis thus ignores the fact that fuel purchased abroad also leads to emissions of CO_2. This is due to international accounting rules in which these CO_2 emissions are attributable to the country of sale.

The measure has co-benefits such as reduced atmospheric pollution and noise, improved accessibility for the remaining motorists and fewer accidents as a result of the fall in the volume of traffic.

Analysis results
The high shadow price is especially due to the additional expenses for buying fuel and the large reduction in revenue due to reduced fuel sales, an expected increase in border trade and losses from other vehicle-related taxation. On the other hand, there will be fewer accidents, as well as reduced congestion, noise and atmospheric pollution.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, including co-benefits DKK/tonne CO_2 eq.	Shadow price, excluding co-benefits DKK/tonne CO_2 eq.	Net costs, Annuity, DKK mill./year		
				State	Business	Households
Increase of fuel tax	743,000	2,663	3,628	-133	594	965

Uncertainties
The results are sensitive to the assumptions regarding, for example, elasticity, border trade effect etc.

Increased biofuel blending mandate

Description
This measure involves increasing the requirement for the concentration of biofuel in petrol from 10% to 11% from 2020.

Assumptions
Specifically, it is required that an additional 1% biofuel is blended with petrol and diesel respectively.

The analysis is based on current legislation and therefore does not take account of effects of possible future ILUC regulation or similar. The analyses assume that only imported 1st generation biofuels are used to meet the requirement. The analyses use only the price difference between petrol/bioethanol and diesel/biodiesel, respectively. In practice, an average price difference for the period January 2012 to July 2012 has been used. It is assumed that the necessary infrastructure is already in place. This includes storage and blending facilities. Therefore, the costs of the measure only include those costs that are linked to the fuel (including taxes and costs etc. associated with the derived effects).

With regard to the co-benefits, it is assumed that there will be no change in air pollution etc. However, the derived effects will result in a general reduction in traffic activities, so there will be a reduction in the transport sector's environmental impact.

Analysis results
The high shadow price is mainly due to the increased cost of purchasing fuel, loss of state revenue through increased border trade and loss of taxation revenue from the fuels replaced by biofuels. These costs are only offset to a limited extent by reduced air pollution, noise, accidents and congestion as a result of the reduced volume of traffic caused by the increased costs.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, including co-benefits DKK/tonne CO_2 eq.	Shadow price, excluding co-benefits DKK/tonne CO_2 eq.	Net costs, Annuity, DKK mill./year		
				State	Business	Households
Increased biofuel blending mandate	163,000	1,499	1,672	105*	45	66

* Including the public sector (DKK 1.6 mill.).

Uncertainties
There is generally large uncertainty concerning the price of biofuels (and petrol).

Statutory requirement for 1% advanced biofuel in petrol from 2020

Description
This measure consists of a statutory requirement for the replacement of 1 percentage point of total petrol consumption with advanced biofuels. Advanced biofuels are produced from bio waste materials. Biomass, which could be used as food for humans or animals, is not used.

Assumptions
The analysis is based on current legislation and therefore does not take account of effects of possible future ILUC regulation or similar. The mandate is supplementary to the energy agreement's mandatory 10% biofuel blending in 2020. The mandate will displace a corresponding quantity of fossil fuel. The analyses assume that only imported 2nd generation biofuels are used to meet the requirement. It is assumed that advanced biofuels will cost around DKK 5.5/litre more than 1st generation bioethanol. It is assumed that the necessary infrastructure is already in place. Therefore the measure only includes costs that are linked to the fuel (including taxes and costs etc. associated with the derived effects).

The co-benefits include reduced atmospheric pollution, noise and accidents etc. as a result of the reduced volume of traffic caused by the higher petrol prices.

Analysis results
The high shadow price is especially due to the additional expenditure on purchasing 2nd generation biofuels, loss of state revenues from taxation, including losses from increased border trading, other vehicle-related taxation, reduced supply of labour and an associated distortionary cost from collecting other state taxes to replace the lost revenue. These costs are only offset to a limited extent by reduced atmospheric pollution, noise, accidents and congestion as a result of the reduced volume of traffic caused by the increased costs.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, including co-benefits DKK/tonne CO_2 eq.	Shadow price, excluding co-benefits DKK/tonne CO_2 eq.	Net costs, Annuity, DKK mill./year		
				State	Business	Households
Statutory requirement for 1% advanced biofuel in petrol from 2020	85,000	4,455	4,937	175*	15	142

* Including the public sector (around DKK 2.3 mill.)

Uncertainties
There is generally large uncertainty concerning the price of biofuels (and petrol).

Compulsory driving lessons in energy-efficient driving

Description
This measure proposes statutory requirements to make energy-efficient driving techniques a more important part of driving instruction, and through requirements for driving school vehicles to be equipped with consumption meters

Assumptions
To a certain extent, energy-efficient driving is already included in the existing compulsory driving instruction. Experience from courses in energy-efficient driving show that many drivers can achieve up to a 20% reduction in fuel consumption by adopting an appropriate driving technique. In the analysis it is assumed that all the driving instructors in Denmark (around 2,000) must take a course in energy-efficient driving, and, from 2014, an extra compulsory module of 4 hours' duration is introduced for each of the 65,000 new driving licences issued every year in Denmark.

Co-benefits are not included in the calculation, though the measure will potentially lead to a limited reduction in atmospheric pollution and reduce the risk of accidents.

Analysis results
Overall, the advantage of the proposal is more energy-efficient driving whilst the disadvantages concern the costs of the increased driving tuition.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, excluding co-benefits	Net costs, Annuity, DKK mill./year		
		DKK/tonne CO_2 eq.	State	Business	Households
Compulsory driving lessons in energy-efficient driving	17,000	1,189	10	1	19

Uncertainties
If energy-efficient driving can be promoted further within the normal instruction programme, then the number of extra hours can be reduced, thus reducing the welfare economic cost. On the other hand, there is a risk that the energy-efficient driving skills will be forgotten over time, so the effect may be overestimated.

Subsidy to and certification of private-municipal collaboration on green commercial transport

Description
The measure consists of subsidies to a green transport certification scheme for municipalities and enterprises, and an effort for the adoption of fuel-saving measures in the transport sector, such as tyre pressure indicators or speed limiters.

Assumptions
Commercial transport makes up a significant proportion of transportation use, and therefore provides an opportunity for a systematic effort that could reduce CO_2 emissions from the transport sector. Based on existing experience of green certification schemes for transport companies and municipalities, there is a good basis to expand this effort for CO_2 reductions in a systematic way.

In the analyses it is assumed that 500 companies and 60 municipalities are certified before 2020. Regarding the companies, it is assumed that they have an average fleet of 10 lorries and an annual expense of DKK 12,000/year per company for greenhouse gas reduction efforts. In the case of municipalities, an annual expense of DKK 60,000/year is assumed. The level of the expenses has been assessed on the basis of experience of the cost of measures that are typically introduced in the first years of a certification scheme. The analysis of the potential for CO_2 reduction is based on knowledge about commercial and municipal fleets and transport patterns, and on an annual reduction in these of at least 2%/year.

Co-benefits in the form of reduced air pollution (nitrous oxide particles and sulphur dioxide) have not been included in the analyses.

Analysis results
The low shadow price is especially due to the potential for savings on fuel, which are taken to be greater than the costs for energy saving equipment and the campaign task force.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, excluding co-benefits	Net costs, Annuity, DKK mill./year		
		DKK/tonne CO_2 eq.	State	Business	Households
Commercial transport and private-municipal collaboration (subsidies and certification)	30,000	-585	22	-31	

Uncertainties
There is an uncertainty regarding the precise effects of the measure due to factors such as uncertainty about the reference scenario.

Vehicle procurement requirements for the public sector

Description
In this measure, the Danish Transport Authority's existing recommendations for public procurement of vehicles will be made compulsory, and minimum requirements for fuel economy will be introduced in order to reduce fuel consumption and CO_2 emissions.

Assumptions
The recommendations for tendering and procurement of vehicles for public-sector transport are assumed to be made compulsory. The minimum requirements for fuel economy are assumed to be increased regularly – as is the case with green taxis – in parallel with market introduction of more fuel-efficient cars. It is assumed that municipalities, regions and state companies review their fleets and plan replacement of their vehicles so the greatest possible environmental benefit is achieved. For municipalities and regions the measure is assumed to be financially neutral. The municipalities and the regions are expected to recoup the additional cost of the more effective vehicles in the fuel they save. For the state the analysis includes revenue loss from fuel taxes as a result of the improved fuel economy. Additionally, the state may also receive reduced revenues from vehicle taxes, however, this is not included in the analysis. This will raise the shadow price of the measure.

Co-benefits concerning air pollution and road safety have not been included as the overall effects are expected to be very small.

Analysis results
The low shadow price is especially due to the significant fuel savings. The increased costs for vehicle procurement increase the costs of this measure.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, including and excluding co-benefit DKK/tonne CO_2 eq.	Net costs, Annuity, DKK mill./year		
			State	Municipalities & business	Households
Vehicle procurement requirements for the public sector	42,000	235	9	-10	

Uncertainties
There is some uncertainty as to the precise effects of the measure, including the reference scenario. A greater effect can be achieved by a targeted replacement of the vehicles with the highest CO_2 emissions in the fleet, however, it is not possible to quantify the effect of a targeted policy.

Biofuel blending subsidies for heavy vehicles

Description
This measure consists of a subsidy to cover the price difference between blends with 10% and up to 30% biofuels in defined fleets of lorries, buses and vans. Biofuel blending results in a displacement of petrol and diesel, and thus a reduction of emissions of greenhouse gases is achieved.

Assumptions
With the energy agreement of 2012 it was decided to increase the requirements for importers and producers of fuel, from the present 5.75% biofuel to 10% in 2020. The transition process towards a higher biofuel content beyond 10% in 2020 assumes the support of a subsidy. The analyses only include the effect caused by the replacement of fossil fuel with biofuel, as it is assumed that the higher concentrations alone will not change behaviour because the market price remains the same due to the subsidy. Only the CO_2 effect is included in the analysis. A total subsidy of DKK 244 mill., including administration of the scheme, has been assumed in the analysis.

Co-benefits such as concerning air pollution and road safety, are not included in the analysis as they are expected to be largely unchanged.

Analysis results
The high shadow price is especially due to the extra cost of purchasing biodiesel.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, including co-benefits DKK/tonne CO_2 eq.	Net costs, Annuity, DKK mill./year		
			State	Business	Households
Biofuel blending subsidies for heavy vehicles	39,000	1,581	14	0	

Uncertainties
Uncertainties with this analysis are minor. However, changes in the price of biofuels could have an impact on the effect of the measure.

Extended tax exemption for electric cars beyond 2015

Description
In this measure, the existing tax exemption for electric cars up to and including 2015 is extended to include the period 2016-2018. Extending the period will stimulate demand for electric cars and thus reducing consumption of oil and the associated CO_2 emissions.

Assumptions
Extension of the tax exemption period is expected to lead to sales of 10,000 electric cars in the period 2016-2018. It is assumed that the tax exemption will not increase total sales of new cars, but that the 10,000 electric cars will fully replace sales of petrol or diesel powered cars. An average of 16,000 kilometres driven per year is assumed, regardless of whether a conventional car or an electric car is used.

The analysis for CO_2 emissions also takes into account a content of biofuels in petrol and diesel of 4.8% and 6.8%, respectively, up to 2019, and 10% in both petrol and diesel from 2020.

Co-benefits in the form of reduced noise from the replacement of 10,000 conventional cars with electric cars, are included in the analysis. A positive effect in the form of reduced air pollution is not included in the analysis, as it is expected that air pollution from new petrol and diesel cars in 2016-2018 will be limited.

Analysis results
The high shadow price is especially due to revenue loss from taxes from conventional cars which have been replaced by electric cars.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, including co-benefits DKK/tonne CO_2 eq.	Shadow price, excluding co-benefits DKK/tonne CO_2 eq.	Net costs, Annuity, DKK mill./year		
				State	Business	Households
Promotion of electric cars through extended tax exemption	16,000	4,462	5,238	51		-9

Uncertainties
The assumed sales figure of 10,000 electric cars in the period 2016-2018 is subject to significant uncertainty. The shadow price in DKK/tonne CO_2 is not, however, sensitive to the number of electric cars exempted from tax, providing the assumptions are otherwise unchanged. On the other hand, the CO_2 reduction potential and the cost for the state and households is sensitive to the number of electric cars sold.

Tax exemption for plug-in hybrid cars 2013-2015

Description
In order to promote sales of plug-in hybrid cars owners are exempted from paying registration tax, annual vehicle weight tax and ownership tax in the period 2013-2015.

Assumptions
It is assumed that the tax exemption will contribute to sales totalling 5,000 plug-in hybrid cars in the period 2013-2015. It is assumed that the tax exemption will not increase total sales of new cars, but that the 5,000 plug-in hybrid cars will fully replace sales of petrol or diesel powered cars.

The fundamental assumptions used are the same as for the measure concerning electric cars.

The co-benefits are reduced noise and air pollution as a result of replacing 5,000 conventional cars with plug-in hybrid cars. The majority of these benefits concern noise reductions.

Analysis results
The high shadow price is especially due to revenue loss from taxes on the conventional cars.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, including co-benefits DKK/tonne CO_2 eq.	Shadow price, excluding co-benefits DKK/tonne CO_2 eq.	Net costs, Annuity, DKK mill./year		
				State	Business	House-holds
Tax exemption for plug-in hybrid cars 2013-2015	7,000	5,012	5,938	27		-6

Uncertainties
The assumed sales figure of 5,000 cars in the period 2013-2015 is subject to significant uncertainty. Plug-in hybrid cars were first launched on the Danish market in 2012, and very few have been sold with the taxes in place.

The shadow price in DKK/tonne CO_2 is not however sensitive to the number of plug-in hybrid cars exempted from tax, providing the assumptions are otherwise unchanged. On the other hand, the CO_2 reduction potential and the cost for the state and households is sensitive to the number of plug-in hybrid cars sold.

Tax relief on natural gas for heavy transport

Description
This measure is an indemnification scheme. The tax on compressed natural gas (CNG) for heavy transport is reduced to DKK 15/GJ (around DKK 0.60/m3) in order to promote sales of natural gas vehicles in the transport sector.

Assumptions
Heavy goods vehicles powered by gas are typically DKK 300,000 more expensive than the corresponding diesel powered vehicle. CNG is cheaper than diesel, but, for reasons such as the extra cost of the vehicles and the lack of infrastructure, no natural-gas powered heavy goods vehicles have been sold in Denmark. At the present time, the lower price of gas can evidently not completely offset the additional cost of the vehicle within the relevant payback period. The tax reduction will lead to revenue losses for the state, even though natural gas vehicles use more energy than diesel vehicles.

It is assumed that as a result of the tax reduction, around 5% of heavy goods vehicle sales will switch from diesel to natural gas from 2013; corresponding to around 400 vehicles in 2013. It is assumed that the transition will continue up to 2020, when it is estimated that 5% of all heavy goods vehicles in Denmark will be powered by natural gas. From 2020 and up to 2042, it is assumed that this proportion will remain constant. Co-benefits concerning air pollution, accidents etc., have not been included, as natural gas vehicles are subject to the same requirements as diesel lorries in relation to emissions and safety.

It is also assumed that the tax reduction will not increase total sales of new vehicles, but that sales of natural-gas powered heavy goods vehicles will substitute diesel powered vehicles.

Analysis results
The high welfare economic cost is primarily due to revenue loss for the state from fuel taxes, and a relatively small reduction in greenhouse gases. The tax relief is targeted less narrowly than the measure regarding subsidies for natural-gas powered heavy goods vehicles, and therefore the CO_2 reduction is greater.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, including and excluding co-benefit DKK/tonne CO_2 eq.	Net costs, Annuity, DKK mill./year		
			State	Business	Households
Tax relief on natural gas for heavy transport	2,000	1,798	15	-60	

Uncertainties
The effect of tax relief on conversion to natural gas is subject to considerable uncertainty.

Promotion of natural gas for the transport sector through subsidies for natural gas powered heavy goods vehicles

Description

This measure consists of subsidies to cover some of the additional procurement cost of the vehicle, in order to stimulate demand for gas powered heavy transport vehicles.

Assumptions

Lorries and busses powered by compressed natural gas (CNG) or biogas (CBG) are today typically DKK 300,000 more expensive than the corresponding diesel powered vehicles. CNG is cheaper than diesel, but, for reasons such as the extra cost of the vehicles and the lack of infrastructure, no natural-gas powered vehicles for heavy transport are sold in Denmark. At the present time, the lower price of gas can evidently not completely offset the additional cost of the vehicle within the relevant write-off period. In the analysis, the size of the subsidy is set at 35% of the additional cost of the purchase. This instrument targets specific fleets of heavy vehicles and, in the analysis, is assumed to run for three years. In the analysis, there is a subsidy pool of around DKK 135 mill. for the period 2013-2015, corresponding to around DKK 45 mill./year. In addition to this, there are costs for administration and targeted information in order to overcome the barrier of lack of knowledge about the conversion to gas.

CNG service stations should be located in connection to the natural gas grid. Use of natural gas does not result in a large displacement of CO_2, and the advantages as climate change mitigation effort will therefore only be realised in the long term, if it becomes cost-effective to phase additional upgraded biogas into the natural gas grid, or to produce it specifically for vehicle use, additionally to the production that is assumed as a result of the energy agreement from 22 March 2012.

The analysis below shows the effect of phasing natural gas into fleets up to 2020. The CO_2 benefit will be around 300 tonnes CO_2 eq. If, before 2020, the measure can contribute to a greater production of biogas than was expected as a result of the energy agreement, then the CO_2 benefit will increase. In this context the measure could save around 50,000 tonnes CO_2 eq. if 50% biogas is phased in, and around 100,000 tonnes CO_2 eq. if the fleets run exclusively on biogas in 2020.

Analysis results

The shadow price is relatively high, partly due to the modest reductions of CO_2 emissions, and partly due to the additional costs of extra investments in vehicles.

Co-benefits have not been analysed for atmospheric pollution, accidents etc., because natural-gas powered lorries have to comply with the same emissions and safety requirements as diesel lorries. The state receives revenues from fuel tax, because natural-gas powered vehicles use more energy than diesel vehicles. Additionally, there is a saving for the industry, as natural gas in particular is cheaper than diesel. There is a knowledge barrier for the success of the measure, and this must be overcome with a focused information campaign to the larger fleets, where there could potentially be an interest in conversion to gas powered operations.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, including and excluding co-benefit DKK/tonne CO_2 eq.	Net costs, Annuity, DKK mill./year		
			State	Business	Households
Promotion of natural gas for the transport sector through subsidies for natural-gas powered vehicles	317	941	-1	-4	0

Uncertainties

There is considerable uncertainty as to the effects of the measure. In particular, the greenhouse gas reduction of the measure depends on whether the vehicles are run on natural gas or whether additional biogas is phased in for use by the converted fleets.

Qualitative descriptions of transport measures

Preparation of a bicycle strategy to promote cycling

Description

This measure consists of developing a bicycle strategy. In itself the strategy will not lead to CO_2 effects, but the strategy can prepare a foundation to ensure that there continues to be a high proportion of cyclists on the road, and that this proportion increases.

Assumptions

The strategy could cover possible measures such as super cycle highways, green waves, bicycle parking etc., in order to improve conditions for cyclists throughout the country, so that the bicycle becomes a more attractive, widely used and a safe form of transport, both for commuters and as a leisure activity.

In addition to CO_2 reductions and the resulting climate change mitigation effect, the increase in bicycle traffic will also have other advantages in the form of positive effects on congestion and health, and in the form of noise reduction and reduction of other air emissions.

Pilot programme for energy-efficient transport solutions

Description

An instrument in the form of a pilot programme to support the development of more energy-efficient transport solutions could contribute to achieving the long-term aim of a transport sector independent of fossil fuels. Such a pilot prime could support tests and demonstration projects within the areas of new vehicle technology, alternative fuels, efficiency improvement of goods transport, and commuter and mobility planning.

The instrument could contribute to overcoming the start-up inertia that exists for realising new ideas, partly through subsidies for development, and partly by creating focus and interest in new ideas and knowledge sharing about development in the areas mentioned.

Support for production of advanced biofuels

Description

In this measure a subsidy is given for the operation of a facility to produce advanced biofuels based on straw.

The bioethanol that is produced in such a facility will not replace fossil fuels, but other bioethanol, probably produced abroad. This measure will therefore not directly contribute to the realisation of Denmark's national climate change objectives.

The welfare economic implications of this measure have not been analysed, as the measure will not in itself result in reduced CO_2 emissions.

Revenue-neutral tax reform on passenger cars

Description

As promised in the government platform "A Denmark that stands together", the government will submit a revenue-neutral reform of taxes on passenger cars in order to promote environmentally and climate-friendly vehicles. The effects depend upon the final design of the reform.

The welfare economic implications of this measure have not been analysed.

European Union regulatory developments for vehicle technology

Description

In the European Union, the regulations concerning vehicle design and equipment are, in most cases, covered by common rules. However, there is an opportunity to achieve great CO_2 reductions by amending and improving the EU rules in a number of areas in which Denmark does not have the possibility to establish regulation nationally.

These include:

- Changing the regulations for setting speed limiters on lorries, so that they must be set at 80 km/h instead of 90 km/h.
- Giving truck manufacturers the possibility to produce streamlined lorries that are a little longer than normal lorries but with a much lower wind resistance and better safety properties, without compromising on truck-bed length.
- Requiring that passenger cars are equipped with an intelligent speed adaptation system, so the car, via GPS positioning and a built-in digital map, always 'knows' the local speed limit. This improves road safety and reduces CO_2 emissions.

Analyses show that an estimated CO_2 reduction of 220,000 tonnes could be achieved in 2020 if all three of the amendments to the EU regulations mentioned above were implemented.

The welfare economic implications of this measure have not been analysed.

The EU's 2020 recommended targets for CO_2 emissions from cars and vans are made mandatory

Description

In 2009 the EU introduced performance standards for passenger cars so that new cars sold from 2015 must not emit more than 130 grams CO_2 per kilometre on average. An additional target for average emissions from new passenger cars is 95 grams CO_2 per kilometre from 2020. Denmark met the 2015 requirements already in 2011.

All new vans must not emit more than an average of 175 grams CO_2 per kilometre from 2017. An additional target for average emissions from new vans is 147 grams CO_2 per kilometre from 2020.

A proposal has now been submitted that stipulates the necessary measures and funds needed to ensure realisation of an average emissions limit of 95 grams CO_2 per kilometre from 2020 for passenger cars and 147 grams CO_2 per kilometre for vans from 2020.

It has been assessed that if the proposal is implemented in a Danish context it will result in a CO_2 reduction of around 210,000-350,000 tonnes in 2020. The effect of the measure depends on the basis for the analyses, and on how much of future technological development is due to the regulation. Furthermore, this will not be a national requirement – but a requirement to vehicle manufacturers.

The welfare economic implications of this measure have not been analysed.

Subsidy for demonstration projects concerning goods distribution outside rush hour

Description

In this measure, goods distribution is spread over more hours during the day. This will mean, for example:

- Lorries and vans will drive with greater fuel economy outside peak hours, when there is not so much traffic, allowing more stable driving pattern with less stopping and starting.
- Hauliers will achieve improved utilisation of their equipment.
- The road network will be relieved of heavy traffic during the day.

Lorries and vans can drive with greater fuel economy and achieve significant time savings by driving outside peak traffic hours instead of at rush hour. A CO_2 reduction of around 30% is not unrealistic.

Around 30% of the total road freight involves distribution to cities. A conservative estimate is that 1-5% of this transport could be switched to off-peak hours.

The instrument consists of providing a subsidy for demonstration projects on off-peak hours distribution, including subsidies for low-noise equipment; thus paving the way for a greater voluntary expansion of off-peak hours distribution.

The analyses show that greenhouse gas emissions could be reduced by between 3,000 and 15,000 tonnes CO_2 equivalents in 2020.

Subsidies for campaigns on energy-efficient driving techniques

Description

The measure consists of continued information campaigns to increase focus in Denmark on the significance of driving style for fuel consumption.

Assumptions

Up to 20% of fuel consumption can be saved by driving energy-efficiently. Despite the significant financial saving for individuals, it is often seen that the potential is not exploited.

It is possible to launch more campaigns targeted at motorist's awareness of energy-efficient driving. The effect of the campaign is uncertain. Motorists often change behaviour for a short time after a campaign, but subsequently have a tendency to forget the message and eventually return to old habits. A well-planned campaign can achieve long-lasting effects.

Shadow prices have not been analysed for campaign measures. This is due to the uncertain greenhouse gas reduction effect and that the measure is relatively small.

Subsidies for campaigns about energy labelling of cars and vans

Description

The measure consists of continued information campaigns to increase awareness of energy labelling of passenger cars and vans.

Assumptions

From 2010-2011, the proportion of Danes that were familiar with the energy label increased from 61% to 66%. This is assumed to have led to more car buyers purchasing a vehicle with an energy classification one class up from the one they would otherwise have bought. In this way, up to 12% fuel consumption per kilometre can be saved. Shadow prices have not been analysed for this campaign measure.

Subsidies for campaigns promoting energy-efficient tyres

Description

This measure consists of a campaign effort on the compulsory tyre label which provides information on, for example, rolling resistance (impact on the climate) and wet braking in order to encourage sales of tyres with lower rolling resistance, energy consumption and CO_2-emissions.

Assumptions

The difference between the fuel consumption of a car with energy class A-rated tyres (the best tyres in terms of rolling resistance) and energy class G-rated tyres (tyres that only just meet the minimum requirements for rolling resistance) is around 7%. Despite the significant financial saving for individuals, it is often seen that the potential is not exploited.

Campaigns can be launched to increase motorist's awareness of energy-efficient tyres. The effect of the campaign is uncertain. Motorists often change behaviour for a short time after a campaign, but subsequently have a tendency to forget the message and eventually return to old habits. A well-planned campaign can achieve long-lasting effects.

Subsidies for courses in energy-efficient driving techniques for municipalities and transport operators

Description

The instrument consists of subsidies for courses aimed specifically at the larger fleet owners such as municipalities or transport companies, who want to train their workers in energy-efficient driving.

Assumptions

The subsidies target purchases by transport companies of systems for registering and tracking specific driver's fuel consumption, with a view to introducing incentive schemes to promote energy-efficient driving. Every municipal worker who has attended a training course, is assumed to be able to achieve a 5% fuel saving. For bus drivers the potential for fuel saving is up to 10%.

More campaigns can be launched to increase the driver's awareness of energy-efficient driving. The effect of the campaign is uncertain. Drivers often change behaviour for a short time after a campaign, but afterwards have a tendency to forget the message and eventually fall back into old habits. A well-planned campaign can achieve long-lasting effects.

Due to the uncertain reduction effect the shadow prices have not been analysed.

Agriculture

Greenhouse gas emissions from agriculture primarily consist of methane and nitrous oxide from livestock production and the use of fertiliser. Moreover, there are considerable emissions from soil carbon pools in connection with land use and land-use changes.

For many of the measures there are considerable synergies between the measures to reduce greenhouse gas emissions and other policy goals, e.g. to reduce nitrogen leaching and ammonia emissions. Such co-benefits have been valued (see the methodology memo). The co-benefits contribute to making many measures economically attractive from a welfare economic perspective and therefore they have a wider environmental perspective than just reducing greenhouse gas emissions. In the descriptions below of agricultural measures, the overall reduction potential of a measure represents the accumulated reduction of methane, nitrous oxide and carbon sequestration. In the more detailed background memos, these potentials have been analysed without carbon sequestration as well. For agricultural measures, it is assumed that costs cannot be passed on to consumers, because agriculture is considered to be a price-taker in the international commodity market.

Measures are grouped by whether they relate to biomass as an energy resource, reduction of emissions from livestock farming, management of livestock manure and fertilisation, or agricultural use.

Agriculture	**Reduction**	**Shadow price**	**Net costs**			
	Including carbon sequestration	Including co-benefits and carbon sequestration	State budget		Agri culture	House-holds
	1000 tonnes CO_2 eq. in 2020	DKK/tonne CO_2 eq.	Comment	Annuity DKK mill./year	Annuity DKK mill./year	Annuity DKK mill./year
Mitigation measures with potential of more than 50,000 tonnes CO_2 eq.						
Biogas from livestock manure, common biogas plants; IFRO assumptions; Tax on manure not used in biogas production.	132	625		-191	204	11
Biogas from livestock manure, common biogas plants; Upgrading; IFRO assumptions; Tax on manure not used in biogas production.	132	1,007				
Biogas from livestock manure, common biogas plants; livestock manure with maize silage; IFRO assumptions; excluding synergy effects; Tax on manure not used in biogas production.	187	1,195		-192	213	23
Biogas from livestock manure, common biogas plants; Danish Energy Agency assumptions; Tax on manure not used in biogas production.	140	453		-191	204	11

Agriculture	**Reduction**	**Shadow price**	**Net costs**			
	Including carbon sequestration	Including co-benefits and carbon sequestration	State budget		Agri culture	Households
	1000 tonnes CO_2 eq. in 2020	DKK/tonne CO_2 eq.	Comment	Annuity DKK mill./year	Annuity DKK mill./year	Annuity DKK mill./year
Mandatory acidification of slurry in new livestock buildings	97	-417		0.3	45	0
– Cattle slurry	32	-350			19	0
– Pig slurry	65	-483			27	0
Requirement for fixed cover on slurry tanks	78	2,321			134	
– Cattle slurry	25	2,989			61	
– Pig slurry	53	1,652			73	
Feed with fat for dairy cows promoted through taxes	141	1,036		-33	133	0
– Conventional dairy cows	128	414		-16	76	
– Organic dairy cows	12	5,413		-17	57	
Feed with fat for dairy cows promoted through subsidies	141	1,074		64	35	0
Tax on artificial fertilisers without nitrification inhibitors	335	1,844		0	410	0
Reduction of nitrogen quota by 10%	175	-1,810		0	166	0
Subsidy for establishment of 100,000 hectares of energy crops, total	181	26	Subsidy for establishment, DKK 53 mill./ year 2013-2020	84	-40	0
– Organic soil	18	153		9	-2	0
– Sandy soil	145	-194		66	-32	0
– Clay soil	18	119		9	-6	0
Requirement for catch crops on an additional 240,000 ha, total	156	-2,235		1	64	0
– Sandy soil	110	-3,375		0.7	47	
– Clay soil	46	-1,094		0.3	17	
Requirement for intermediate catch crops on an additional 240,000 ha, total	167	-532		1	67	0

Agriculture	Reduction	Shadow price	Net costs			
	Including carbon sequestration	Including co-benefits and carbon sequestration	State budget		Agri culture	House-holds
	1000 tonnes CO_2 eq. in 2020	DKK/tonne CO_2 eq.	Comment	Annuity DKK mill./year	Annuity DKK mill./year	Annuity DKK mill./year
– Sandy soil	89	-978		0.6	36	0
– Clay soil	78	-25		0.5	31	0
Subsidy for conversion of 100,000 ha of arable land to permanent pasture, total	295	1,292		333	0	0
– Sandy soil	149	181		102	0	0
– Clay soil	146	2,404		231	0	0
Subsidy for conversion of arable organic land to grassland with continued drainage	102	1,973		135	0	0
Subsidy for conversion of arable land on organic soils to nature	481	150		149	0	0
Subsidy for afforestation, total	474	501		220	0	0
– Sandy soil	232	-217		37	0	0
– Clay soil	242	1,188		183	0	0
Mitigation measures with potential of less than 50,000 tonnes CO_2 eq.						
Requirements for cooling of slurry in pig sheds	6	-16,083		0	-71	0
Changed animal feed for cattle other than dairy cows promoted by tax	11	3,646		-17	44	0
Changed animal feed for cattle other than dairy cows promoted by subsidies	11	3,849		28	0	0
Optimisation of dairy production through prolonged lactation period	17	-25		0	-0.3	0
Stricter requirements on nitrogen utilization for gasified livestock manure	48	-1,663		0	35	
Stricter requirements for nitrogen utilization for selected types of livestock manure (mink slurry, poultry slurry, effluent manure and deep litter)	17	-1,608		0	14	0
Reduced tax breaks on fuel for agricultural machinery	36	3,073		-96	98	

Agriculture	Reduction	Shadow price	Net costs			
	Including carbon sequestration	Including co-benefits and carbon sequestration	State budget		Agri culture	House-holds
	1000 tonnes CO_2 eq. in 2020	DKK/tonne CO_2 eq.	Comment	Annuity DKK mill./year	Annuity DKK mill./year	Annuity DKK mill./year
Measures only described						
Thermal gasification						
Biomass refining						
Reduced tillage						
Straw for thermal gasification and with return of biochar to the soil						
Nitrification inhibitors for livestock manure						
Promotion of crop rotation with perennial crops/grass fields						
Larger share of legumes in grass fields						
Permanent grass fields						
Plant breeding; choice of species and provenance in forestry						
Farm model for regulation of greenhouse gas emissions from agriculture						
Nitrate and sulphate in feed for dairy cows						
Genetic selection						

Changed emission factors and Global Warming Potentials

In the context of the Climate Policy Plan and the Catalogue of Climate Change Mitigation Measures, historical and future emissions have been analysed in accordance with the guidelines decided at COP17 for calculating greenhouse gas emissions.

The Climate Convention has established a panel of scientific experts – the Intergovernmental Panel on Climate Change (IPCC). On the basis of the most recent scientific knowledge, this panel regularly prepare new proposals for guidelines for analysing greenhouse gas emissions from different activities, including the different Global Warming Potentials (GWP) of different greenhouse gases in relation to CO_2. The countries under the Climate Convention discuss the IPCC proposals and subsequently adopt the guidelines to be followed when the parties report their greenhouse gas emissions to the Secretariat of the Climate Convention. At COP17 in Durban in December 2011, it was decided that the IPCC's proposal for updating of emission factors and GWPs from 2006/2007 should be used to analyse and report emissions in the emission year 2013 and onwards.

The Climate Policy Plan is aimed at Denmark's future emissions. In order to assess the implementation of the Climate Policy Plan over time, figures and analyses in the plan should be based on the future guidelines for national statements and reports to the UN on greenhouse gas emissions.

The most profound changes in the new IPCC guidelines are the new emission factors for activities in agriculture, as well as new GWP values for a number of greenhouse gases, including methane and nitrous oxide, which account for the majority of agricultural emissions. With the new guidelines, methane from cows and livestock manure represents about 60% of the emissions of methane and nitrous oxide from agriculture, compared to 44% analysed on the basis of the old guidelines. Similarly, nitrous oxide produced from turnover of nitrogen in livestock manure, soil and watercourses, represents a smaller percentage of about 40% with the new guidelines.

Tax on livestock manure not used for biogas production

Description

A tax can be levied on slurry that is not already utilised for biogas production. This enhances the incentive to use slurry for biogas production beyond the current level provided by subsidies and tax exemptions. When slurry and other livestock manure is anaerobically digested in biogas plants, the organic substances are fermented into methane, which can be used for energy production thereby displacing natural gas and the corresponding emissions of fossil CO_2. Anaerobic digestion of livestock manure also reduces emissions of methane and nitrous oxide to the atmosphere, as the fermentation process reduces the content of decomposable carbon and thus the potential for generation of these greenhouse gases in the livestock manure. Anaerobic digestion of slurry ultimately results in less soil carbon sequestration, as a part of the carbon in the livestock manure is decomposed in the biogas plant.

Assumptions

The Agreement on Green Growth established the target that 50% of the total amount of slurry must be processed for energy purposes by 2020. This analysis assumes an increase in the use of livestock manure in biogas production by additionally 10% of the total amount of livestock manure, i.e. from 50% to 60% of total livestock manure production. Anaerobic digestion of biomass may overlap with others of the measures analysed, such as acidification of slurry and slurry cooling.

Below, four different scenarios are presented for increasing biogas production from additionally 10% of the total amount of slurry. In particular the scenarios differ with respect to the composition of input to the biogas plants. The most important assumptions and results of the analyses for the individual scenarios are summarised in the table on the next page. It should be noted that the four scenarios cannot be compared in relation to reduction of greenhouse gases, as they include different amounts of livestock manure and/or alternative amounts of biomass. However, the analyses for shadow prices are comparable. Scenarios 1-3 have been designed by the Danish Centre for Food and Agriculture at Aarhus University in collaboration with the Department of Food and Resource Economics, which has been responsible for the analyses. Scenario 4 has been designed by the Danish Energy Agency.

As co-benefits, anaerobic digestion will increase the fertiliser value of slurry and generate higher nitrogen utilization in livestock manure and less leaching of nitrogen into the waterways.

Tax on livestock manure not used in biogas production	Raw slurry, '000 tonnes	Separated slurry, underlying slurry, '000 tonnes	Maize silage, '000 tonnes	Solid manure, '000 tonnes	10% energy loss summer
	Of which dry matter, '000 tonnes	of which dry matter, '000 tonnes	of which dry matter, '000 tonnes	of which dry matter, '000 tonnes	
Scenario 1: IFRO basis	**1,180**	**3,060**	0	0	Yes
	71	106	0	0	
Scenario 2: IFRO basis + upgrade to natural gas	**1,180**	**3,061**	0	0	4% loss
	71	106	0	0	
Scenario 3: IFRO basis with maize silage added, excl. synergy effects	**2,221**	**1,708**	**393**		Yes
	134	50	130		
Danish Energy Agency Scenario 4: Solid manure displaces separated slurry, no 10% summer loss, displaced natural gas included, higher content of dry matter in pig slurry	**1,180**			**353**	No
	75			106	

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Note: Input amounts correspond to the assumptions in underlying spreadsheets and, in some cases, slightly deviate from the input figures in background memos, as volumes are adapted to the capacity of the entire number of plants selected.

Scenario 1 is the baseline scenario for scenario two and three. Some important basic assumptions are: Expansion is made with common biogas plants for a number of farms where biogas is used in decentralised small-scale CHP units. With expansion of biogas from 50% to 60% of the amount of livestock manure, scenarios 1-3 assume that it will be necessary to include areas with relatively low livestock density. In order to reduce costs of transportation of slurry to common biogas plants a substantial amount of the slurry has to be separated. Finally, 10% of the total energy production from the CHP unit is assumed not to be utilised, as waste heat from cooling cannot be fully exploited in the summer.

Shadow costs with co-benefits are slightly lower than shadow costs without co-benefits. The co-benefits primarily consist of better utilization of the nitrogen content and reduced nitrogen leaching. This scenario will generate a surplus to agriculture. The relatively high shadow price is especially due to the fact that investment and operating costs exceed the value of energy production and increased fertiliser value. Costs of slurry separation alone represent about 20% of total costs.

In **Scenario 2** the biogas output is upgraded to natural gas quality in order to obtain better market access, among other things the energy loss of 10% during the summer can be avoided. Upgrading means an energy loss of about 4%, and other costs. Upgrading means that shadow prices are considerably higher than in the baseline scenario: DKK 1,007/tonne CO_2 eq. with carbon sequestration and co-benefits relative to DKK 625/tonne CO_2 eq. in scenario 1. Thus, upgrading entails significantly higher costs than in the baseline scenario. Due to increased costs the farmer will receive no return unlike in scenario 1.

In **Scenario 3** part of the separated slurry in the baseline scenario is replaced by maize silage so that maize silage amounts to 10% of the total underlying volume of slurry, cf. access to using other energy crops in connection with biogas production under the new subsidy rules adopted in connection with the energy agreement. The volume of dry matter, biogas production and the number of biogas plants increase considerably compared to the baseline scenario, as there must be sufficient capacity to process about 10% of the volume of slurry. Maize yields a high biogas output per tonne and is therefore used in e.g. Germany as an energy supplement in biogas plants. The reduction increases to about 187,000 tonnes CO_2 eq. /year, primarily due to increased biogas production and corresponding displacement of natural gas. Shadow prices also increase: DKK 1,195/tonne CO_2 eq., including carbon sequestration and co-benefits, and DKK 1,285/tonne CO_2 eq., including carbon sequestration, but excl. co-benefits. An important reason for the higher shadow price compared to the baseline scenario is that maize is a considerably more expensive feed stock than slurry. Before the tax instrument, this measure yields a considerably higher economic return to agriculture per tonne of slurry than the baseline scenario. However, the annual costs for households and the state are about twice as high (before tax).

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	Number of plants at full expansion 2020	Reduction, full expansion, incl. carbon sequestration	Shadow price, with co-benefits	Shadow price, without co-benefits	Net costs Annuity, DKK mill./year			Economic return for agriculture per tonne of slurry (excl. tax)
		Tonnes CO_2 eq. 2020	DKK/tonne CO_2 eq.	DKK/tonne CO_2 eq.	State	Agriculture	Households	DKK/tonne of slurry (present value)
Scenario 1	6 of 700 tonnes/ day each	132,000	**625**	**791**	-191	204	11	7.2
Scenario 2	6 of 700 tonnes/ day each	132,000	**1,007**	**1,171**				0
Scenario 3	11 of 700 tonnes/ day each	187,000	**1,195**	**1,285**	-192	213	23	19.8
Scenario 4	6 of 700 tonnes per day	140,000	**453**	**482**	-191	204	11	

Scenario 4 deviates from the baseline scenario on three points: It is assumed that a future expansion will utilise solid manure corresponding to its share of the overall amount of fertilisers measured as dry matter, i.e. about one-third. Solid manure mainly comprises deep litter from cattle and poultry buildings. So far solid manure has not been used in biogas production to any major extent, because up to now resources more suitable for biogas production have been available in terms of industrial waste. Compared to scenarios 1-3, solid manure displaces separated slurry/maize, and thereby save costs for separation.

In addition, the dry matter content of pig slurry is assumed to be higher than in the baseline scenario: 5.5% against 4.9% in the baseline scenario. Among other things this is based on the assumption that sow slurry, which has a considerably lower dry matter content than slurry from porkers, is not included.

Finally, it is assumed that there will be no energy loss during summer due to the lack of demand for heating during this period. This is partly due to expectations that the current efforts to effectively integrate biogas in the energy supply system will be successful, eliminating the bottlenecks in relation to utilization which today constrain some of the biogas plants.

Another argument for not determining the energy loss in the summer is that, during the summer period, biogas-fired electricity production probably mostly displaces electricity production from coal-fired condensation plants. These plants cannot exploit waste heat in the summer either, and they emit significantly higher emissions per unit produced than biogas and natural gas CHPs. The premise for assuming 10% energy loss in the summer is that the reference for biogas-based CHP is a natural-gas-fired CHP, which will normally reduce production in the summer if heating demands are low. In contrast, biogas CHP is assumed to run all summer, as biogas production is more or less constant.

The welfare economic shadow price, including co-benefits is DKK 453/tonne CO_2 eq. against DKK 482/tonne CO_2 eq. excl. co-benefits. The somewhat lower shadow prices compared to the other scenarios are due to cost-savings on separation and energy crops.

Analyses have been made on a number of other scenarios for biogas from livestock manure: addition of conventional grass, organic grass and grass from nature management. These analyses are included in the background memo, see the introduction.

Uncertainties

There are uncertainties about many factors in the biogas analyses: Future natural gas prices, prices of energy crops and competing crops, respectively, and the composition of livestock manure input in the event of expansion from 50% to 60% of the volume of livestock manure, etc.

Mandatory acidification of slurry in new livestock buildings

Description

Approvals to build new livestock buildings may include a requirement for acidification of the slurry in the buildings by adding concentrated sulphuric acid. This reduces methane emissions from slurry in the livestock buildings by approx. 60%. At the same time, ammonia emissions are significantly reduced.

Assumptions

In 2010, Denmark produced about 18 mill. tonnes of cattle slurry and about 22 mill. tonnes of pig slurry. It is assumed that 10% of the slurry can be acidified through regulation by 2020.

Slurry acidification equipment is expected to be established at farm level. It is assumed that the equipment has a life time of 15 years. The measure will have establishment costs and operating costs including maintenance, electricity, lime and sulphuric acid consumption.

This measure overlaps with biogas production from biomass. Acidification in livestock buildings reduces the possibility of utilizing slurry in biogas production, as the acidified slurry is difficult to use for biogas. The sulphur content will not have negative effects on biogas production, if the share of acidified slurry/sulphurous fibre does not exceed 10% of the total input of biomass. Greenhouse gas emissions in connection with production of sulphuric acid and agricultural lime have not been not included in the analyses.

Analysis results

Reduced ammonia evaporation is a considerable co-benefit of acidification, and if the value of this is included, the measure has a negative welfare economic shadow price. On the contrary, if the value of the ammonia emission is not included, the measure will have a shadow price of DKK 1,100-1,500/tonne CO_2 eq. The large difference between the CO_2 shadow prices with and without the value of co-benefits shows that slurry acidification must primarily be considered an environmental policy measure to reduce ammonia pollution. In addition to the value of the ammonia reductions, the driver behind the result is the enhanced value of slurry that has higher concentrations of nitrogen and sulphur than normal.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, including co-benefits DKK/tonne CO_2 eq.	Shadow price, excluding co-benefits DKK/tonne CO_2 eq.	Net costs, Annuity, DKK mill./year	
				State	Agriculture
Acidification 10% cattle slurry	32,000	-350	1,469		19
Acidification 10% pig slurry	65,000	-483	1,134		27
Total acidification	**97,000**	**-417**	**1,302**	**0.3**	**45**

Uncertainties

The costs of sulphuric acid represent 54% of the costs for agriculture in this analysis. The results are therefore sensitive to changes in the price of sulphuric acid.

Requirement for fixed cover on slurry tanks *

Description

This mitigation measure involves a requirement for covering up slurry tanks with tent canvas or other fixed cover. This requirement will cover about 40% of the total Danish volume of slurry. The measure will reduce methane and ammonia emissions from stored slurry.

Assumptions

Currently, there is a statutory requirement for digester supernatant layers based on straw or similar in slurry tanks. The supernatant layer reduces ammonia evaporation and emissions of methane. Establishing fixed covers on slurry tanks, in addition to the supernatant layer, will provide for additional reductions in emissions of ammonia and methane. A tent canvas is the least expensive type of fixed cover.

A fixed cover is deemed relevant for about half of the total Danish volume of slurry. Of this volume, 10-12% already has a fixed cover. The potential for fixed cover therefore includes an additional approx. 40% of the total volume of slurry. In terms of potential, the mitigation measure overlaps with other initiatives aimed at livestock manure, such as biogas processing and acidification of slurry.

Covering slurry tanks with tent canvas reduces methane emissions by 15% while reducing ammonia evaporation. Reduced ammonia evaporation during storage increases the nitrogen content of the slurry applied to fields. The value of slurry from tanks with a cover will therefore be higher. Nitrogen emissions are not reduced by a cover.

Establishing covers on slurry tanks entails both establishment and maintenance costs. The tent canvas needs to be re-established every five years. As mentioned, there will also be financial benefits of establishing covers on slurry tanks. This is because the reduced ammonia evaporation leads to a higher content of nitrogen in the slurry, which raises the value of the slurry. Furthermore, the capacity for storing slurry will increase, because the cover will prevent rainwater from entering the tank and taking up tank capacity. Avoiding rainwater in the slurry also reduces the costs associated application on fields. On the other hand, the costs of application are increased, as emptying tanks becomes more difficult when the tanks have fixed covers.

Analysis results:

For cattle and pig slurry under one, the shadow price is around DKK 2,300 per tonnes CO_2 equivalents with co-benefits, increasing to around DKK 2,900 per tonne CO_2 equivalents without co-benefits. The relatively high shadow prices are due to the fact that the costs of fixed cover are not offset by the savings in the form of increased fertiliser value, reduced distribution costs due to reduced rainwater, and reduced ammonia evaporation. Pig slurry has lower reduction costs because the reduction in greenhouse gas emissions is greater, which results in a higher denominator in the CO_2 shadow price compared with cattle slurry.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, including co-benefits DKK/tonne CO_2 eq.	Shadow price, excluding co-benefits DKK/tonne CO_2 eq.	Net costs, Annuity, DKK mill./year Agriculture
Covers on pig slurry	53,000	1,652	2,060	73
Covers on cattle slurry	25,000	2,989	3,727	61
Covers, in total	**78,000**	**2,321**	**2,894**	**134**

* An error was detected after the publication of the original publication in Danish. The revised results are only printed in the translation. A memo about the revisions can be found on the website of the Danish Energy Agency (in Danish).

Feed with fat for dairy cows promoted through taxes or subsidies

Description
The measure consists either of imposing a tax per cow not being fed with additional fat, or to provide subsidies for feed with additional fat. The addition of more fat to cattle feed reduces methane emissions from the animals.

Assumptions
As a basis for the analyses, the composition of feed is changed for 80% of the conventional dairy cows and 25% of the organic dairy cows. In addition, the number of conventional dairy cows is assumed to drop to about 406,000 in 2020, whereas the number of organic dairy cows is assumed to increase to about 126,000. The subsequent methane emissions from the slurry may increase if fat is added to the feed. However, due to uncertainty, these effects have not been included in the analyses. Furthermore, the analyses assume that there are no co-benefits of the measure in the form of changes in other emissions than methane, and that the changed feed plans are composed such that milk yields are not affected. Prior to a possible decision about implementation of the measure, it will be necessary to examine whether an increase in feeding with rapeseed products may affect the taste of the milk produced, the fat content and other milk quality parameters. Also animal welfare aspects need to be examined.

As the measure is not economically advantageous for farmers; it is assumed that a tax of DKK 197/year per cow is imposed on dairy cows not fed with fat. Alternatively, the analyses include a subsidy for dairy cows fed with more fat of DKK 176 /cow per year.

Analysis results
As seen in the table, there is a considerable difference in the shadow price for conventional cows (DKK 414/tonne CO_2 eq.) and organic cows (DKK 5,413/tonne CO_2 eq.). This is because organic feed with fat is considerably more expensive than non-organic feed; also relative to the price of normal feed. The shadow price for both types of cows as a whole is almost identical, whether the instrument is a tax or a subsidy. Agriculture will still have net expenses, even with the subsidy. This is due to the fact that the subsidy will only to a limited extent compensate organic dairy production for the additional costs associated with adding fat to the feed. Some organic farmers are still expected to change the feed composition to avoid being seen as less "green" than conventional dairy producers.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price with tax	Shadow price with subsidy	Net costs, Annuity, DKK mill./year			
				Tax		Subsidy	
		DKK/tonne CO_2 eq.	DKK/tonne CO_2 eq.	State	Agri-culture	State	Agri-culture
Conventional cows	128,000	414		-16	76		
Organic cows	12,000	5,413		-17	57		
Feed with fat for dairy cows, total	**141,000**	**1,036**	**1,074**	**-33**	**133**	**64**	**35**

Uncertainties
The costs of the measure depend to a great extent on the prices of feed, which have increased significantly in recent years, particularly the prices of organic feed. Furthermore, in light of new research results, the climate impact of the measure has been written down by more than a half compared to previous analyses.

Tax on artificial fertiliser without nitrification inhibitors

Description
To create incentives to add nitrification inhibitors to all commercial fertilizers a tax can be imposed on commercial fertilisers without nitrification inhibitors. Additives to ammonium-containing fertilisers can reduce emissions of nitrous oxide.

Assumptions
Basically, nitrification inhibitors can be added to all commercial fertilisers. Nitrification inhibitors are estimated to be able to reduce emissions of nitrous oxide by 38% after the application of commercial fertilisers, corresponding to a total of 335,000 tonnes CO_2 eq. by 2020. Commercial fertiliser consumption is assumed to be constant in the entire period from 2013 to 2042. There may be overlaps with other measure which reduce consumption of commercial fertiliser, including reduction of the nitrogen quota by 10% and requirements for better utilisation of certain types of livestock manure. No certain increases in yields from using nitrification inhibitors have been registered; utilisation of such therefore leads to additional expenses for agriculture, corresponding to the additional cost of adding nitrification inhibitors.

Analysis results
This results in a societal shadow price of DKK 1,844/tonne CO_2 eq. The high shadow price is due to increased costs for agriculture as well as tax distortions in connection with the increased operating costs. Agriculture will have annual expenses of DKK 410 mill.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, including co-benefits	Net costs, Annuity, DKK mill./year	
		DKK/tonne CO_2 eq.	State	Agriculture
Nitrification inhibitors	335,000	1,844	0	410

Uncertainties
Nitrification inhibitors are not approved for use on Danish arable land. There are also uncertainties about the price of nitrification inhibitors, which may fall if the demand increases. There are also state support problems connected with charging taxes on commercial fertilisers only and not, e.g. on livestock manure.

Reduction of nitrogen quota by 10%

Description
The nitrogen quota can be reduced by 10% for conventional farms in Denmark. If the use of nitrogen is reduced, emissions of nitrous oxide will be diminished, and at the same time nitrogen leaching and ammonia emissions will also be reduced.

Assumptions
The total N quota for conventional farms is 144 kg N per hectare. This measure imposes a cost on agriculture, as the application of less fertiliser reduces crop yields, which is not fully offset by the savings from buying less fertiliser.

The measure reduces the emissions of nitrous oxide from nitrogen turnover in the soil. Furthermore, nitrogen leaching from the root zone is reduced by around 10,000 tonnes nitrogen per year and ammonia emissions are diminished by 552 tonnes nitrogen per year. Both effects result in reduced emissions of nitrous oxide. There may be some overlaps with other measures which reduce the utilisation of commercial fertilisers. This may lower the effect of a 10% reduction in the amount of commercial fertilisers.

Analysis results
This measure leads to economic losses for agriculture of DKK 166 mill. per year, which contributes to the high shadow price of DKK 1,425/tonne CO_2 eq., when the value of the environmental effects is excluded. The CO_2 shadow price with these effects is DKK -1,810/tonne CO_2 eq. The large difference in the shadow prices shows that the measure has a wider environmental policy scope than reductions in greenhouse gas emissions.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, including co-benefits	Shadow price, excluding co-benefits	Net costs, Annuity, DKK mill./year	
		DKK/tonne CO_2 eq.	DKK/tonne CO_2 eq.	State	Agriculture
Reduction of N quota	175,000	-1,810	1,425		166

Uncertainties
Future updates of nitrogen response functions are expected to show greater losses as a result of reduced nitrogen application than the existing models. The farm and welfare economic costs and benefits have been estimated conservatively.

Subsidy for establishment of 100,000 hectares of energy crops

Description
There are already subsidies which ensure the profitability of producing willow chips on a large part of the agricultural area. The additional subsidy is to offset the uncertainties regarding future price changes for alternative crops and willow chips. This measure leads to increased soil carbon sequestration as well as reduced nitrogen leaching. In addition lower energy consumption reduces CO_2 emissions.

Assumptions
The scenario assumes that energy willow is planted on 10,000 ha of organic soil, 80,000 ha of sandy soil and 10,000 ha of clay soil. It is assumed that increased use of willow chips will displace wood chips, but not fossil fuels, which means that there is no reduction of CO_2 in the CHP sector. The measure also has co-benefits in the form of reduced nitrogen leaching of 2,375 tonnes from the root zone and reduced ammonia evaporation equal to 39 tonnes of nitrogen. Revenues from the sale of willow chips are assumed to follow international market prices for wood chips and wood pellets, which are expected to increase up to 2035. This measure may overlap with other land demanding measures such as conversion of arable organic soil to grassland, planting of catch crops and short-term catch crops.

Analysis results
As seen in the table, the shadow price varies somewhat between the three types of soil, which is due to differences in the net return to farmers from growing other crops on the land, and the co-benefits primarily in the form of reduced nitrogen leaching.

	Reduction, including carbon sequestration, tonnes CO_2 eq. 2020	Subsidy	Shadow price, DKK/tonne CO_2 eq. with co-benefits	Shadow price, DKK/tonne CO_2 eq. without co-benefits	Net costs, Annuity, DKK mill./year State	Net costs, Annuity, DKK mill./year Agriculture
Willow chips, 80,000 ha sandy soil	145,000	Additional	-194	561	66	-32
Willow chips, 10,000 ha clay soil	18,000	Additional	119	516	9	-6
Willow chips, 10,000 ha organic soil	18,000	Additional	153	905	9	-2
Willow chips, 100,000 ha in total	**181,000**	Additional	**26**	**661**	**84**	**-40**

Uncertainties
There are uncertainties about the effect of the subsidy on the total area of energy willow. Already today, growing of energy willow yields higher economic returns than many crops on sandy soil and clay soil. With the assumed price increase of willow chips, there will be positive net returns for all types of soil in the long term. However, the additional return is relatively low, and planting of energy willow will only be profitable if the land is used for this crop for a number of years, and if the price of willow chips increases as assumed. Therefore, it is uncertain whether the additional profit will be sufficient to overcome farmers' reluctance to restricting the land use to this crop for a number of years.

Requirements for catch crops on an additional 240,000

Description
Requirements may be set for the size of the catch crop area for various types of farms. Planting of catch crops after harvest of the primary crops will increase carbon sequestration in the soil and reduce nitrogen leaching. On the other hand, emissions of nitrous oxide will increase. However, overall, net emissions of greenhouse gases will be reduced.

Assumptions
Catch crops will be established on an additional 240,000 ha in addition to the areas already planted with catch crops. It is assumed that the 240,000 ha will be distributed between 63,000 ha of clay soil and 177,000 ha of sandy soil. Sandy soil and clay soil have different cultivation properties, and therefore also vary in relation to emissions of nitrous oxide and nitrogen leaching. This measure results in reduced nitrogen leaching from the root zone of about 9,500 tonnes of nitrogen/year and 72 tonnes less ammonia evaporation per year. Farmers will have annual expenses connected with the establishment of catch crops, but there will also be a small saving in the form of reduced fertiliser requirement.

The increased soil carbon sequestration is the only reason that total greenhouse gas emissions will be reduced as a result of more catch crops.

Analysis results
In particular, it is the nitrogen leaching reduction that makes this measure attractive from a welfare economic perspective. Nitrogen leaching is reduced the most on sandy soil, which on the other hand is a larger source of nitrous oxide emissions than clay soil. Overall, this measure is more cost effective on sandy soils compared to clay soils, provided that the co-benefits are included – primarily the reduction in nitrogen leaching. If co-benefits are not included, the measure is most attractive for clay soil, as, in contrast to sandy soil, there are no nitrous oxide emissions from catch crops on clay soil. An increase in catch crop areas must primarily be considered as an environmental-policy measure to reduce nitrogen leaching.

	Reduction, including carbon sequestration, tonnes CO_2 eq. 2020	Shadow price, DKK/tonne CO_2 eq. with co-benefits	Shadow price, DKK/tonne CO_2 eq. without co-benefits	Net costs, Annuity, DKK mill./year	
				State	Agriculture
Catch crops 63,000 ha clay soil	46,000	-1,094	560	0.3	17
Catch crops 177,000 ha sandy soil	110,000	-3,375	658	0.7	47
Catch crops total 240,000 ha	**156,000**	**-2,235**	**609**	**1**	**64**

Requirements for intermediate catch crops of an additional 240,000 ha

Description

Requirements can be set to establish intermediate catch crops to a varying extent for different farm types, e.g. depending on the crop rotations. Cultivation of intermediate catch crops can sequester carbon in the soil in terms of root as well as surface biomass. Moreover, nitrogen emissions to the aquatic environment are reduced. As for catch crops there is a slight increase in the emission of nitrous oxide.

Assumptions

In 2008, the area with winter cereals amounted to about 840,000 ha. It is considered realistic that it will be possible to grow intermediate catch crops on about 240,000 ha of winter cereals, distributed between 110,000 ha on clay soil and 130,000 ha on sandy soil. As the intermediate catch crops are implemented using differentiated regulatory instruments this measure will need to be phased in gradually up to 2020. Establishment of intermediate catch crops will be associated with costs for farmers.

Cultivation of intermediate catch crops will reduce nitrogen leaching from the root zone by about 4,200 tonnes N per year by 2020. The increase in soil carbon sequestration is the only reason for a net reduction in greenhouse gas emissions as a consequence of this measure.

Analysis results

There is a major difference in the CO_2 shadow price for this measure on clay soil and sandy soil, i.e. DKK -25/tonne CO_2 eq. and DKK -978/tonne CO_2 eq., respectively. This difference is due to less reduction in nitrogen leaching from clay soil. Generally, the value of the co-benefit in the form of reduced nitrogen leaching is crucial for the attractiveness of this measure from a welfare economic perspective. Intermediate catch crops therefore have a wider environmental perspective than greenhouse gas reductions alone.

	Reduction, including carbon sequestration, tonnes CO_2 eq. 2020	Shadow price, including co-benefits DKK/tonne CO_2 eq.	Shadow price, excluding co-benefits DKK/tonne CO_2 eq.	Net costs, Annuity, DKK mill./year	
				State	Agriculture
Intermediate catch crops 110,000 ha clay soil	78,000	-25	810	0.5	31
Intermediate catch crops 130,000 ha sandy soil	89,000	-978	841	0.6	36
Intermediate catch crops on a total of 240,000 ha	**167,000**	**-532**	**826**	**1**	**67**

Uncertainties

There are ongoing field trials with short-term catch crops, and therefore the knowledge base for carbon sequestration and reduction of nitrogen leaching must be considered less certain than for ordinary catch crops.

Subsidy for conversion of 100,000 ha of arable land to permanent pasture

Description
The measure involves increasing the existing subsidy provided to landowners for converting arable land on mineral soils (not naturally wet) to permanent grass fields. This provides an economic incentive to increase the area with permanent grass, which will increase the capacity for carbon sequestration, which accounts for half of the reduction potential. The other half of the reduction is from reduced nitrous oxide emissions and lower fuel consumption. Nitrogen leaching and ammonia evaporation will also be reduced.

Assumptions
It is assumed that 100,000 ha of arable land is converted from arable farming to extensively managed permanent grassland, equally distributed between sandy soil and clay soil. The areas suitable for conversion under this measure to some extent overlap with the areas that may be designated under the measures concerning afforestation and increased willow cultivation. On half of the area, nature management will be in the form of mechanised hay-production, and on the other half, it will be all-year grazing with beef cattle.

For the farmer, the costs are in the form of lower earnings than from traditional use as well as costs associated with nature management. To create an incentive for permanent grassland, the farmer may be granted additional subsidies to cover his costs. It is assumed that the measure will not generate additional EU subsidies for Denmark and that the Danish government will pay the entire subsidy.

Analysis results
The shadow price is significantly lower for this measure on sandy soils than for clay soils. This is because the farmer has higher opportunity cost on clay soils than on sandy soils, and because there are considerably higher co-benefits in the form of reduced nitrogen leaching on sandy soil. Therefore, from a welfare economic perspective it is most advantageous to convert sandy soil to permanent grassland.

	Reduction, including carbon sequestration, tonnes CO_2 eq. 2020	Shadow price, including co-benefits DKK/tonne CO_2 eq.	Shadow price, excluding co-benefits DKK/tonne CO_2 eq.	Net costs, Annuity, DKK mill./year	
				State	Agriculture
50,000 ha sandy soil	149,000	181	1,323	102	0
50,000 ha clay soil	146,000	2,404	3,074	231	0
Conversion of land to grassland, total	**295,000**	**1,292**	**2,199**	**333**	**0**

Uncertainties
The estimate for the CO_2 effect is reduced compared with previous assessments. Costs of subsidies will depend on future land rents, which in turn depend on e.g. crop prices.

Subsidy for conversion of arable land on organic soils to nature

Description
This measure is a subsidy corresponding to the average costs for agriculture of setting aside land due to reduced production. It is assumed that the entire subsidy for setting aside land and for nature management is to be paid by the Danish government.

Termination of drainage and cultivation of organic soils will reduce the application of nitrogen fertiliser and associated emissions of nitrous oxide, as well as CO_2 emissions from agricultural machinery. Furthermore, the decomposition of the carbon pool in the organic soil is reduced, in particular if drainage of the soil is terminated. However, this will be gradually counterbalanced by increased emissions of methane.

Assumptions
It is assumed that 35,000 hectares of drained, but naturally wet, organic land are converted gradually from arable farming to permanent grassland during the period 2013-2020. The term 'organogenic' refers to soil with more than 20% organic material (>12% carbon). Where drainage is terminated it is assumed that nature management will be by grazing. If drainage continues, it is assumed that nature management will be in the form of hay making or the like. Furthermore, land conversion will provide co-benefits in the form of reduced nitrogen leaching and ammonia evaporation.

Analysis results
The magnitude of the welfare economic costs and benefits depends largely on whether or not drainage is terminated. Conversion with termination of drainage leads to a significantly greater reduction of greenhouse gases, as oxidisation of the carbon in the organogenic soil is reduced most if drainage is stopped. Without termination of drainage, state expenditure on subsidies for nature management will be lower. This is because hay-making, which is a less costly management practice than grazing, can be considered as feasible if drainage is continued. Finally, the effect on nitrogen leaching has great significance for the welfare economic cost, as the measure will result in significantly lower nitrogen leaching from the converted areas.

	Reduction, including carbon sequestration, tonnes CO_2 eq. 2020	Shadow price, DKK/tonne CO_2 eq. with co-benefits	Shadow price, DKK/tonne CO_2 eq. without co-benefits	Net costs, Annuity, DKK mill./year State	Net costs, Annuity, DKK mill./year Agriculture
Conversion of organic soil with termination of drainage	481,000	150	603	149	0
Conversion of organic soil without termination of drainage	102,000	1,973	2,570	135	0

Uncertainties
There is uncertainty about the precise carbon content in the soil of converted land and thus about the reduction effect. It is difficult to estimate the effect of subsidies as the opportunity cost for landowners varies depending on the type of farming and on the area required to dispose of manure.

Subsidy for afforestation *

Description
The existing subsidy for afforestation on mineral soils (not naturally wet) can be increased, making silviculture as economically attractive as traditional crop farming. To ensure a cost-effective distribution of an increased afforestation subsidy, the subsidy can be differentiated between sandy soil and clay soil. Afforestation leads to greenhouse gas emission reductions as the land is no longer cultivated intensively, which means less fertiliser is applied leading to fewer emissions of nitrous oxide. However, the primary climate impact will be in the form of increased carbon sequestration in roots, wood and the forest floor.

Assumptions
It is assumed that a reduction of 474,000 tonnes of CO_2 eq. in 2020 could be achieved by planting an additional 50,000 hectares of mixed forest on existing arable land up to 2020 (of which 31,000 hectares clay soil and 19,000 hectares sandy soil). The amount of carbon that is stored depends on the age of the forest and the standing volume of wood. The analyses are based on an average carbon sequestration figure over a single rotation age and for common tree species on various soil types. In practice, most carbon is stored outside the 30-year period of the analysis. Carbon sequestration constitutes around 90% of the total greenhouse gas reduction.

Analysis results
The shadow price for afforestation on clay soils is significantly higher than for sandy soil. This is primarily because the agricultural yield on clay soil is higher than on sandy soil, and the loss with conversion to forest is therefore higher. A five-fold increase in the total subsidy for clay soil is required to make silviculture as economically attractive as crop farming. Moreover, the co-benefits in the form of reduced nitrogen leaching are greatest on sandy soil. From a welfare economic perspective, it is therefore more attractive to invest in afforestation on sandy soil. Co-benefits in the form of improved recreational opportunities and increased ground water protection have not been included.

	Reduction, including carbon sequestration, tonnes CO_2 eq. 2020	Shadow price, DKK/tonne CO_2 eq. with co-benefits	Shadow price, DKK/tonne CO_2 eq. without co-benefits	Net costs, Annuity, DKK mill./year	
				State	Forestry
31,000 hectares on clay soil	242,000	1,188	1,424	183	
19,000 hectares on sandy soil	232,000	-217	305	37	
Afforestation on a total of 50,000 ha	**474,000**	**501**	**877**	**220**	**0**

Uncertainties
There is particular uncertainty regarding the assessment of interest rates on land with afforestation and future wood prices. As the effect of carbon sequestration will primarily fall after 2020, the measure will only be useful to a limited extent in achieving the Danish Government's objective of a 40% reduction by 2020.

* An error was detected after the publication of the original publication in Danish. The revised results are only printed in the translation.

Photo: Scanpix / Erik Thomsen

Requirements for cooling slurry in pig sheds

Description
BAT requirements (Best available technology) can be imposed on new constructions or extensions of pig sheds with regards to the cooling of slurry, if the technology is estimated to be beneficial for production. Cooling of slurry reduces emissions of methane from pig sheds.

Assumptions
The measure will be phased in gradually, as it is to be applied to new constructions and/or extensions. In 2020, 10% of all Danish pig slurry will be cooled in slurry channels. The climate impact is solely the reduction of methane emissions. Therefore, the total effect is only 6,000 tonnes CO_2 equivalents in 2020. There is a potential overlap with other mitigation measures such as biomass gasification and acidification of slurry.

The consequences for fuel and electricity consumption on farms are not included, as the savings on heating costs are expected to match the increased costs of cooling. The possible value of reduced odour nuisance and ammonia emissions due to slurry cooling is not included.

Analysis results
Overall, the measure leads to a financial gain for the farmer under the assumption that the facility establishes new sheds, and that the heat can be recovered elsewhere in production. The measure could lead to a total gain for the agricultural industry of around DKK 70 mill. annually. The very low shadow price, DKK 16,083/tonne CO_2 eq., is a result of the relatively large financial advantages in relation to a small reduction potential with the measure.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, excluding co-benefits DKK/tonne CO_2 eq.	Net costs, Annuity, DKK mill./year	
			State	Agriculture
Cooling of slurry	6,000	-16,083		-71

Uncertainty
There is uncertainty concerning the potential for exploiting the heat from the slurry in other production, thus creating an uncertain financial gain for the farmer.

Changed animal feed for cattle other than dairy cows promoted by taxes or subsidies

Description

The measure is assumed to be a tax of DKK 500/tonne CO_2 equivalents for animals that do not receive the intended animal feed composition or a subsidy that covers the costs of the measure. Methane emissions can be reduced by modifying the composition of animal feed for cattle.

Assumptions

'Cows other than dairy cows' refers to young animals, max. two years old. In this case, it is not relevant to increase the proportion of fat in the feed ration, but the share of grass silage can be reduced, and this can be compensated for with more cereals. This gives a 5% reduction in methane emissions.

Andelen af andre typer kvæg, der kan omfattes af ændrede foderplaner, er begrænset, da en stor del af disse dyr går på græs om sommeren, og om vinteren får en fodersammensætning, som er vanskelig at tilpasse med henblik på reduceret metanudledning. Det antages, at tiltaget kun er relevant for konventionelle dyr, hvor fodersammensætningen ændres for 25 pct. af denne bestand. Dette vil udgøre 183.000 dyr i 2020. Dette kan dog medføre statsstøttemæssige problemer.

Før en evt. beslutning om implementering af tiltaget vil der være behov for at undersøge, hvordan dyrevelfærden påvirkes mm.

Analysis results

The high reduction costs are especially due to the fact that cereals are significantly more expensive than grass silage. There is some difference in the shadow price, depending on whether the measure is carried out via a subsidy or a tax. This is due to the greater distortion costs, as the subsidy is expected to be financed via a tax that will cause distortions.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price	Net costs, Annuity, DKK mill./year	
		DKK/tonne CO_2 eq.	State	Agriculture
Changed animal feed, tax	11,000	3,646	-17	44
Changed animal feed, subsidy	11,000	3,849	28	0

Optimisation of dairy production through prolonged lactation period

Description

Milk producers could receive improved guidance on the financial benefits of prolonged lactation periods. However, the knowledge base for the measure is still limited, and therefore it is anticipated that only 10% of the stock will be included under this measure before 2020. Through prolonging the lactation period (the period in which milk is produced) for dairy cows from 13 to 18 months, it is possible to reduce the methane emissions per litre of milk produced. The background for this is that, seen over a lifespan, the cow will have shorter periods where it does not produce milk, while its total methane emissions will remain the same

Assumptions

The effect of the measure is primarily derived from the prolonged calving interval, resulting in fewer calves per cow per year. When the lactation period is prolonged, the consumption of animal feed in the milk-producing periods is proportionately less, which could reduce emissions during milk production by up to 10%. Additionally, there will be a slightly reduced animal feed consumption and a higher percentage of roughage for the dairy cows. In the calculation it is assumed that the total milk production per cow per year is unchanged, whilst there will be a drop in meat production on account of a reduction in the number of calves per cow a year, estimated at 30%. As there will also be reduced animal feed consumption, the measure will be cost-neutral for the agricultural industry.

Analysis results

The analyses show that the measure could reduce methane emissions by around 17,000 tonnes in 2020, and the shadow price for the measure is DKK -25/tonne CO_2 eq. This benefit must be considered in context with the economic analyses which show that the measure entails only a small economic benefit for agriculture.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price	Net costs, Annuity, DKK mill./year	
		DKK/tonne CO_2 eq.	State	Agriculture
Prolonged lactation period	17,000	-25		-0.3

Uncertainties

There is little previous experience with the measure, and therefore there is some uncertainty as to whether the milk yield per cow will be the same. There is also uncertainty as to how much effect an increased information effort will have on agricultural practice with regards to prolonged lactation periods, as the financial benefits for the individual farmers are small.

Stricter requirements for nitrogen utilization for gasified livestock manure

Description
The measure consists of a reduction of the nitrogen standard for gasified livestock manure. The total nitrogen consumption is thus reduced, and also the accompanying emissions of nitrous oxide.

Assumptions
When livestock manure is gasified in a biogas plant, this makes the nitrogen that is fixated in the manure more accessible. An amount of commercial fertiliser corresponding to 11% of the gasified manure can be saved in this way. There is no correction for this saving in the nitrogen standards at this time. It is assumed that commercial fertiliser nitrogen is reduced corresponding to the greater efficiency in utilising the livestock manure nitrogen in gasified slurry. This measure overlaps with other mitigation measures, this leads to a decrease in the benefit of using livestock manure for biogas.

The analysis involves a scenario where 50% of slurry is gasified in 2020. Under the assumptions above, consumption of commercial fertiliser nitrogen will be reduced by 9,300 tonnes per year, with an associated reduction in nitrous oxide emissions. It is expected that, as a co-benefit, ammonia evaporation and nitrogen leaching from the rooting zone will be reduced by 139 tonnes and 2,500 tonnes of nitrogen respectively per year.

Analysis results
As can be seen on the table, there is a significant benefit as a consequence of the reduced nitrogen leaching and ammonia emissions. The measure must therefore primarily be considered as an environmental-policy instrument for reduction of nitrogen leaching and ammonia evaporation – with reduced greenhouse gas emissions as a positive co-benefit.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, including co-benefits DKK/tonne CO_2 eq.	Shadow price, excluding co-benefits DKK/tonne CO_2 eq.	Net costs, Annuity, DKK mill./year	
				State	Agriculture
Stricter requirements for nitrogen utilization for gasified livestock manure	48,000	-1,663	1,303		35

Uncertainties
Future updates of nitrogen-yield ratios are expected to show greater losses with reduced addition of nitrogen than in the existing models. The farm and welfare economic costs and benefits have been estimated conservatively.

Stricter requirements for nitrogen utilization for selected types of livestock manure

Description
Through requirements for improved utilization of nitrogen, the total nitrogen consumption can be reduced, and also the accompanying emissions of nitrous oxide.

Assumptions
The measure covers mink slurry, poultry slurry, liquid manure, solid manure and deep litter, where utilization requirements are already in place. The utilization requirements will be increased by 5% for mink slurry and deep litter, by 10% for poultry slurry and by 20% for liquid manure. The utilization requirement for solid manure is, on the other hand, assumed to be reduced by 10%. The increased utilisation requirements for the mentioned types of livestock manure result in a displacement of commercial fertiliser nitrogen corresponding to 3,100 tonnes of nitrogen per year. The measure may overlap with other mitigation measures – including biomass gasification and reduced nitrogen standard.

As a side-effect, ammonia evaporation will be reduced by 47 tonnes nitrogen per year and nitrogen leaching from the rooting zone will be reduced by 843 tonnes nitrogen per year.

Analysis results
As can be seen on the table, the shadow price falls significantly when the co-benefits – in the form of reduced nitrogen leaching and ammonia emissions – are included in the analysis. The measure must therefore primarily be considered as an environmental-policy instrument for reduction of nitrogen leaching and ammonia evaporation – with reduced greenhouse gas emissions as a positive co-benefit.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, including co-benefits DKK/tonne CO_2 eq.	Shadow price, excluding co-benefits DKK/tonne CO_2 eq.	Net costs, Annuity, DKK mill./year	
				State	Agriculture
Stricter nitrogen requirements for selected types of livestock manure	17,000	-1,608	1,259		14

Uncertainties
Future updates of nitrogen-yield ratios are expected to show greater losses with reduced addition of nitrogen than in the existing models. The farm and welfare economic costs and benefits have been estimated conservatively.

Reduced tax breaks on fuel for agricultural machinery

Description
In this measure, the tax relief on fuel consumption in the agricultural sector is removed. This will reduce fuel consumption and thus CO_2 emissions.

Assumptions
The agricultural industry has lower tax rates on fuels than other sectors. With the introduction of a full process tax on diesel for the agricultural industry, it is expected that farmers will reduce their diesel consumption. However, it is assumed that behavioural changes will be small, as it will still be profitable to cultivate the land. The changes will therefore primarily consist of usage of more fuel-efficient machines, reduced tillage and a slight reduction of land area under cultivation. It is estimated that in total the behavioural changes will give a 4% reduction in fuel consumption. A co-benefit of the tax increase is reduced emissions of particles.

Analysis results
The high shadow price is largely due to the limited financial relevance for the agricultural industry of changing behaviour by limiting diesel consumption. Furthermore, it is expected that the tax will have an almost full effect on agricultural earnings. The modest behavioural changes result in a relatively small CO_2 reduction, which contributes to the high shadow price.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, including co-benefits DKK/tonne CO_2 eq.	Shadow price, excluding co-benefits DKK/tonne CO_2 eq.	Net costs, Annuity, DKK mill./year	
				State	Agriculture
Reduced tax breaks on fuel for agricultural machinery	36,000	3,073	3,074	-96	98

Uncertainties
There is uncertainty regarding the effect on behaviour of a tax increase on agricultural diesel.

Qualitative description of agricultural measures

The qualitative descriptions below cover measures that are described technically and biologically. Due to lack of financial data and/or uncertain scientific data, it is not possible to carry out reliable analyses of CO_2 shadow prices for these measures. In the following, a short description of the technical measures is given.

Thermal gasification

Gas from gasification of biomass, such as straw, could replace coal at power stations. Gasification ensures that the biomass becomes more manageable and increases efficiency. Slagging (fusion of ash on grates) can be avoided by using gasified biomass. The technology also reduces problems related to corrosion, i.e. nutrient salts that attack the boiler walls, which occurs when firing with normal biomass. The biomass ash can be reused as readily accessible nutrients for plants, which is seen as an advantage, for example, in relation to the supply of phosphorus.

DONG has a 6MW demonstration facility (Pyroneer) at Kalundborg, and there is a strategy for further development and marketing of the technology. However, due to insufficient cost data, shadow prices cannot be analysed for this measure.

Biomass refining

With biomass refining, all the organic constituents of the biomass are separated. Full exploitation of all the organic fractions is thereby ensured. These can be used for energy or materials (for example, animal feed or chemicals). After exploitation of the organic material, the nutrients can be returned as fertiliser for plants in agriculture. There is insufficient data available for analysis of CO_2 shadow prices for biomass refining.

Reduced tillage

This measure covers several tillage methods that reduce the work and energy put into arable land. Reduced tillage reduces energy consumption for cultivation of the soil, and, under certain conditions, reduced tillage can lead to increased carbon sequestration in the soil. It is estimated that reduced tillage could give a 33-64% reduction in CO_2 emissions, depending on methods and equipment. A measure such as no-till cultivation could be relevant on around 400,000 hectares of arable land in Denmark, of which around 100,000 hectares are already being cultivated using reduced tillage. It is estimated that a further 200,000 hectares could be converted before 2020. There is a need for an improved development and advisory effort if falls in yields are to be avoided as a result of reduced tillage. It is considered that insufficient data is available concerning Danish farmland for a calculation of the cost of the measure.

Straw for thermal gasification and with return of biochar to the soil

Gasification of straw at high temperatures and low oxygen pressure forms not only bioenergy, but also carbon in a solid form, also known as biochar, which is comparable to charcoal. Biochar is in a solid form instead of becoming CO_2. By treating the straw in this way, the biomass can be returned to the soil and function as a very stable carbon pool in the soil. It is estimated that biochar carbon added to the soil will not decompose over a 20-100-year period, due to its highly stable form, though this is not yet clearly determined. On certain types of arable land it is assumed that biochar could moreover contribute to improved water retention and increased microbiological activity, thus benefiting soil fertility. However, the available data is insufficient to perform analyses of the cost of the measure

Nitrification inhibitors for livestock manure

It is possible to add nitrification inhibitors to commercial fertiliser, in the same way as it is possible to add nitrification inhibitors that reduce the emissions of nitrous oxide from livestock manure applied to fields. Trials have shown a reduction of nitrous oxide varying from 19-60%, with an average of 40%. However, there are no Danish studies available of this method, and the data is therefore considered to be insufficient for analyses of CO_2 shadow prices that will be relevant in a Danish context.

Promotion of crop rotation with perennial crops/grass fields

The planting of perennial crops such as grass or Lucerne in crop rotation will contribute to increased carbon sequestration in the soil. With this measure there is a potential storage of carbon corresponding to 0.257 tonnes CO_2 per hectare per year. The measure is primarily relevant for cattle farming. At present the data is insufficient to determine how the mitigation measure will affect e.g. the methane emissions from the animals. With this uncertainty there is no foundation for calculating the costs of the measure.

Larger share of legumes in grass fields

Legumes are nitrogen-fixing, and it is estimated that nitrogen addition to grass fields could be reduced by 100kg nitrogen per hectare, if there were a greater proportion of legumes. A slight loss of yield might be expected. Such a reduction in nitrogen addition will reduce emissions of nitrous oxide and minimise nitrogen leaching. More research and development is necessary in this area to ensure against yield losses. It is therefore assessed that the data is insufficient for any cost analyses.

Permanent grass fields

Conversion of grass areas in crop rotation to permanent grassland with reduced addition of fertiliser ensures the same carbon storage capacity. Grass fields in crop rotation release stored carbon when ploughed every 2-4 years. A reduction of nitrogen addition reduces emissions of nitrous oxide. However, more research is needed in this area, as well as more experiments on Danish farmland in order to which examine the reduction in yields when converting grass areas in crop rotation to permanent grassland. Due to this lack of data, it has not been possible to perform reliable cost analyses for the measure.

Plant breeding; choice of species and provenance in forestry

Trees are highly productive without the addition of fertiliser. Therefore, trees are attractive for biomass production and carbon sequestration. Under Danish conditions, current production of biomass typically varies between 5 and 15 tonnes dry matter per hectare per year. A disadvantage of wood production is that a single stand needs to be relatively old to provide maximum yield. The optimum harvest time with regard to maximising production is first reached after a number of years. Exactly how many years depends on the species of tree and on the degree of breeding. Wooded areas also have the advantage of functioning as a store for biomass and carbon. The greater the growth, the greater the quantities that can be stored.

Experience has shown that through choice of the best seed sources in the first generation, productivity can be increased by 10 to 30% over a rotation, for a given species. Following this, by choosing from within the best seed sources, productivity can be increased additionally by 10-25% per breeding generation. Financial assessments of breeding programmes under temperate conditions show an internal rate of return (IRR) of around 8-20%. However, breeding requires a relatively large investment and a long investment horizon. Breeding is therefore typically undertaken in the public sector or by large private enterprises.

Forest tree breeding has been carried out in Denmark for the last 50-60 years, most intensively from 1970-2000. Breeding has only been undertaken on a large scale in the public sector, but a number of improved seed sources have been developed and are owned by the private sector, for example, HedeDanmark.

Breeding in Denmark has led to an increased production potential for some species of up to 50%. The most productive species are already able to produce 20 tonnes of dry matter per hectare per year. This puts them among the potentially most productive crops in Denmark.

There is a comprehensive pool of trials for a number of species and extensive knowledge about the capabilities of different seed sources, which until now has only been used to a limited extent. There is therefore great potential to increase growth rates in future forests and other forms of tree plantation. This could be achieved in the relatively near future for species where breeding has already taken place. In the longer term, breeding could be carried out for a range of other species, where challenges such as climate change could also be taken into consideration. It is not possible to give an exact estimate of the reduction potential, as the total effect depends on the size of the area, where the bred material is used, and how quickly the measure is implemented.

Photo: Scanpix / Terkel Broe Christensen

Farm model for regulation of greenhouse gas emissions from agriculture

The regulation problem

Agricultural greenhouse gas emissions originate from a great number of installations and processes in livestock farming and crop production. Only a small proportion of the total greenhouse gas emissions originates from consumption of fossil energy. The main sources are processes that lead to emissions of methane and nitrous oxide and the turnover of carbon in arable land. The extent of these emissions is largely determined in a complicated interaction between the size of the production and the input and processes that are used in the agricultural production.

Regulation of agricultural greenhouse gas emissions has, until now, focused on measures for regulating the size of production, the use of the input, and on the production technology. Realisation of cost-effective regulation requires that every measure that can be used to reduce greenhouse gas emissions should be combined in such a way that the marginal reduction costs are the same for every measure. This must apply at both farm and sector levels. Achieving cost effectiveness by regulation through specific measures requires an extremely comprehensive and detailed information base. In practice this means that regulatory management of pollution levels typically involves general requirements, which do not sufficiently take into account the conditions at a specific farm, and will therefore not provide a specific farmer with the possibility to apply the cheapest solutions in order to fulfil the requirements for pollution reduction.

Alternatively, regulation of agricultural greenhouse gas emissions could be carried out at farm level through requirements for reduction of the total emission of greenhouse gases from the farm, but not requiring utilisation of specific measures or instruments with which to achieve the required reduction. The individual farmer must be assumed to have the best knowledge concerning reduction costs of the different measures. Regulation at farm level will therefore provide the opportunity for cost-effective realisation of a required emission reduction for the farm.

The regulatory framework

In the farm regulation model outlined, it is not necessary for the regulatory authority to obtain information concerning variations in the marginal reduction costs for the different reduction measures. The information problem is solved by giving the individual farmer the freedom, and incentives, to choose the most cost-effective combination of measures. The regulatory authority must, however, have a monitoring and control mechanism that can ensure that the required reduction in greenhouse-gas emissions is achieved. It is not realistic to take direct measurements of a specific farm's emissions of greenhouse gases (or the total for the agricultural industry). Regulation of agricultural emissions of greenhouse gases must therefore be based on various forms of measurable indicators, which reflect the emissions of different greenhouse gases as precisely as possible. In other words, this means that greenhouse gas emission accounts are required at farm level, and which state emissions according to standard figures. In principle, the greenhouse gas emission accounts should be so detailed that the individual farmer can choose between all of the greenhouse gas reducing measures which can contribute to the farm's reduction solution, with the minimum expenditure.

Data requirements and administrative costs

A flexible greenhouse-gas-regulation model at farm level demands comprehensive registration of production, the use of the input and greenhouse-gas-reducing measures at farm level. At present, it is not possible to provide an adequate description of the administrative costs for the agricultural industry and the supervisory authorities of implementation and operation of a farm model for regulation of greenhouse-gas emissions from agriculture. It can, however, be noted that a significant proportion of the measures are already being registered at farm level. This is due to existing requirements for the preparation of fertiliser accounts and reporting of data concerning land use. BAT requirements in connection with expansion of livestock production also mean that some of the greenhouse-gas-reducing measures mentioned are registered at a number of farms.

Conversely, there is no registration of the use and composition of animal feed at individual farm level. This could probably be set up in parallel with the existing system for registration of purchases of commercial fertiliser. Other possible measures, for example prolonged lactation periods for dairy cows, will need a control system to register the average lactation period (the time elapsed between calving) for dairy cows in Denmark. The control system could use data from the detailed registration of cattle that is carried out for veterinary purposes.

Nitrate and sulphate in feed for dairy cows

The measure comprises an increased content of nitrate and sulphate in feed for dairy cows in order to reduce the formation of methane in the digestive systems of ruminants. Some negative co-benefits have been observed, such as an accumulation of nitrate, which can inhibit haemoglobin in the blood from transporting oxygen. There is therefore need for further research to reveal, for example, the optimal phase-in period to avoid accumulation of nitrate. Because of relatively few results within this area in both Denmark and abroad, it is assessed that the data is insufficient to perform economic analyses on this measure.

Genetic selection

It is estimated, that with selective breeding of ruminants with lower methane emissions, a methane reduction of 15% can be achieved by 2050. However, this will require that every ruminant's emissions can be registered, in line with the existing registrations of milk yield and sickness. At the present time this is being carried out on a trial basis. Until now it has only been possible to register dairy cows that have access to robotic milking, where the measurement of methane takes place in the feeding trough. A greater research effort is required to develop this practice. It is therefore considered that there is insufficient data for calculating CO_2 shadow prices for this measure.

The environment

Emissions of different greenhouse gases from a number of subsectors are included in this category: emissions of CO_2 from industrial processes, emissions of F gases from cooling etc., emissions of CO_2, methane, and nitrous oxide from managing waste and wastewater, etc. A number of instruments that can limit these emissions are described in this section.

The environment	**Reduction**	**Shadow price**	**Net costs**			
	Including carbon sequestration	Including co-benefits and carbon sequestration	State		Business	Households
	'000 tonnes CO_2 eq. in 2020	DKK/tonne CO_2 eq.	Comment	Annuity DKK mill./year	Annuity DKK mill./year	Annuity DKK mill./year
Measure with potential of more than 50,000 tonnes CO_2 eq.						
Requirements for separation of plastic from waste for incineration	226	989		68	109	22
Requirements and subsidy for biocover at landfills	390	77	Subsidy of DKK 145 mill. over the first two years	12	4	1
Measure, description only						
Tax on nitrous oxide from wastewater						
Increased tax on certain fluorinated gases (F gases)						
Tax on nitrous oxide from large incineration plants						
Tax on nitrous oxide from catalytic converters in vehicles						

Photo: Affaldvarme Aarhus

Requirements for separation of plastic from waste for incineration

Description

It is possible to establish rules for municipal collection schemes that require households to separate plastic from domestic waste. The effort will result in reduced greenhouse gas emissions from plastic incineration.

Assumptions

At the present time, plastic in waste contributes to electricity and district heating production through waste incineration. When plastic burns, CO_2 is released. In the analysis it is assumed that this energy production will be replaced by electricity and heating from combined heat and power production from coal and biomass at CHP plants in larger cities. The effect of an increased proportion of biomass, as opposed to energy production from fossil sources (such as burning plastic), is particularly important in reducing emissions of CO_2.

In the analysis example it is assumed that almost 45% of plastic in domestic waste will be separated. In the analysis it is assumed that only plastic is separated from domestic waste and sold. Therefore, all the costs of separation included are related to the separation of plastic. Other valuable waste fractions could be separated at the same time, in which case the costs related to the removal of plastic could be lower. A relatively low sales value of DKK 200 per tonne is assumed for the separated plastic, as there are many types of plastic, which makes recycling difficult.

Analysis results

The relatively high shadow price is especially due to the costs of purchasing replacement fuels instead of plastic, and for the high operating costs. These costs are only offset to a limited extent by income from the sale of plastic and savings on incineration. If there were simultaneous separation of other valuable waste fractions, then the costs of separation could be shared by several fractions, which could lead to a reduced shadow price for separation of the plastic.

	Reduction tonnes CO_2 equivalents 2020	Shadow price, including co-benefits	Net costs, Annuity, DKK mill./year		
		DKK/tonne CO_2 eq.	State	Waste producers	Households
Separation of plastic from waste	226,000	989	68	109	22

Uncertainties

There is uncertainty regarding the costs of waste separation and future prices of energy and separated plastic.

Requirements and subsidy for biocover at landfills

Description

It is proposed that the rules should require special biofilters to be established at landfill sites, which convert escaping methane from the landfill to CO_2. For decommissioned landfill sites, it is assumed that central government will fund installation and operation, as there will no longer be any deliveries of waste which can be taxed. Methane is a potent greenhouse gas, with a greenhouse effect 25 times stronger per tonne than CO_2. Therefore, oxidising methane to CO_2 is a significant benefit for the climate.

Assumptions

Organic material deposited in landfill sites which decomposes anaerobically (without oxygen) creates methane. A portion of the methane oxidises into water and CO_2 at the surface of the landfill, whilst the rest is released into the atmosphere. Trials have shown that by establishing windows with special biofilters in the surface of the landfill – also called biocover – emissions of methane from landfill sites can be reduced by around 80%.

There are still 31 active landfill sites with mixed waste, 7 with hazardous waste and around 100 decommissioned landfills, where installation of biocovers is considered relevant. This measure will result in a significant reduction of emissions in 2020, but the emissions reduction will decrease at the rate with which methane emissions from old landfill sites drop, because of the ban on landfilling waste suitable for incineration that was introduced in 1997. There are no co-benefits from this measure.

The measure will require an investment of just over DKK 200 mill. and annual operating expenses of almost DKK 5 mill.

Analysis results

The relatively low shadow price reflects that the costs for establishment and operation are offset by relatively large reductions in methane emissions.

	Reduction, tonnes CO_2 equivalents 2020	Shadow price, including co-benefits DKK/tonne CO_2 eq.	Net costs, Annuity, DKK mill./year		
			State	Waste producers	Households
Biocover	390,000	77	12	4	1

Uncertainties

There is a significant uncertainty regarding the size of methane emissions from landfill sites and the effect of biocovers. There is little previous experience with such a measure, which also means there is uncertainty concerning the investment costs.

Qualitative descriptions of measures related to the environment

Tax on nitrous oxide from wastewater

It is under consideration to reduce nitrous oxide from wastewater treatment plants by imposing a CO_2-equivalent tax on the emissions.

However, there is little experience in this area, in either Denmark or abroad, and it is deemed that it is not possible to identify the reduction potentials.

In this context, it should be noted that measuring emissions of nitrous oxide from wastewater treatment plants is costly and, therefore, the proposed tax model seems inappropriate.

Increased tax on certain fluorinated gases (F gases)

It could be considered to make the tax on F gases fully CO_2 equivalent, as certain gases have a cap at the present time. The most significant source of F gases is released from industrial/commercial refrigeration systems. Releases from household refrigerators and freezers are also significant. Consumption of F gases has fallen since a peak in 1998. As emissions principally come from equipment that is in use and has a long lifespan, there will be a considerable delay before emissions fall. It is estimated that emissions will continue to fall and in 2030 will constitute 15% of the 2008 emissions. There will also be a number of measures, both Danish and European, to reduce emissions.

Tax on nitrous oxide from large incineration plants

It is proposed to impose a CO_2-equivalent tax on nitrous oxide emissions from large incineration plants.

The government has introduced a tax on greenhouse gases other than CO_2 from energy (L 162). The tax only concerns uncombusted methane in connection with energy consumption released from stationary piston engines, for example, for combined heat and power purposes or as a propellant in mechanical processes.

If a tax system were to be fully implemented for methane and nitrous oxide from energy consumption, then the rates for most fuels and applications would be very small.

There is therefore no prospect that there will be any noteworthy effect on CO_2 emissions by introducing an independent nitrous oxide tax.

Tax on nitrous oxide from catalytic converters in vehicles

A CO_2-equivalent tax could be imposed on nitrous oxide emissions from catalytic converters in vehicles.

If the measure is to have any effect, the tax must be differentiated to make consideration for emissions from different types of vehicle/age/etc. However, there is currently no statistical data available on nitrous oxide emissions from different vehicles; i.e. no system is in place to support a differentiated tax model. Furthermore, it is estimated that impacts from the tax on vehicles will be very limited, and therefore it is unlikely that the tax will lead to any noteworthy substitution effect.

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